Feb. 2, 1965 R. FOITZIK ETAL 3,168,701

SHOCK-CURRENT GENERATOR EMPLOYING MEANS TO EFFECT SIMULTANEOUS DISCHARGE OF PLURAL STORAGE DEVICES

Filed Nov. 30, 1960 3 Sheets-Sheet 1

Fig. 1

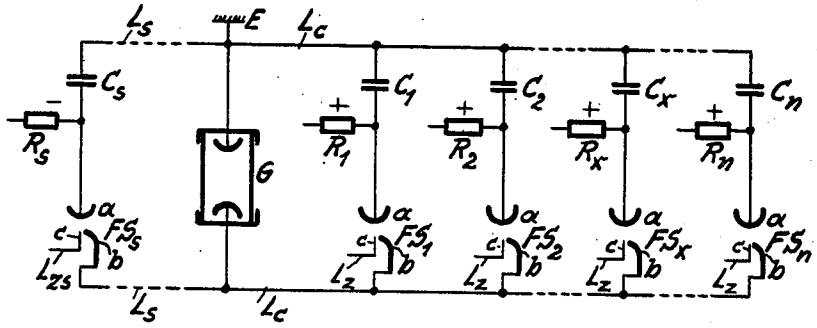


Fig. 2

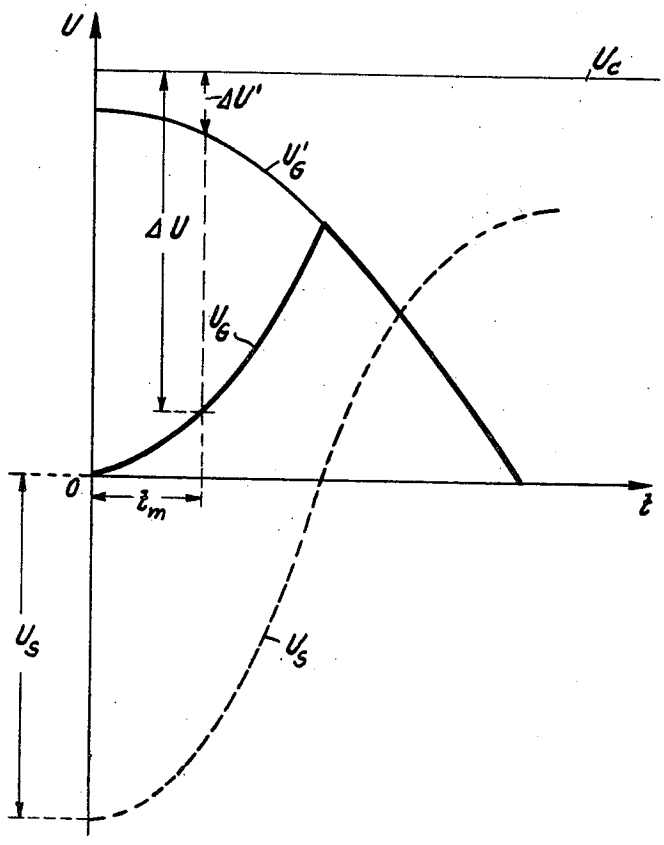
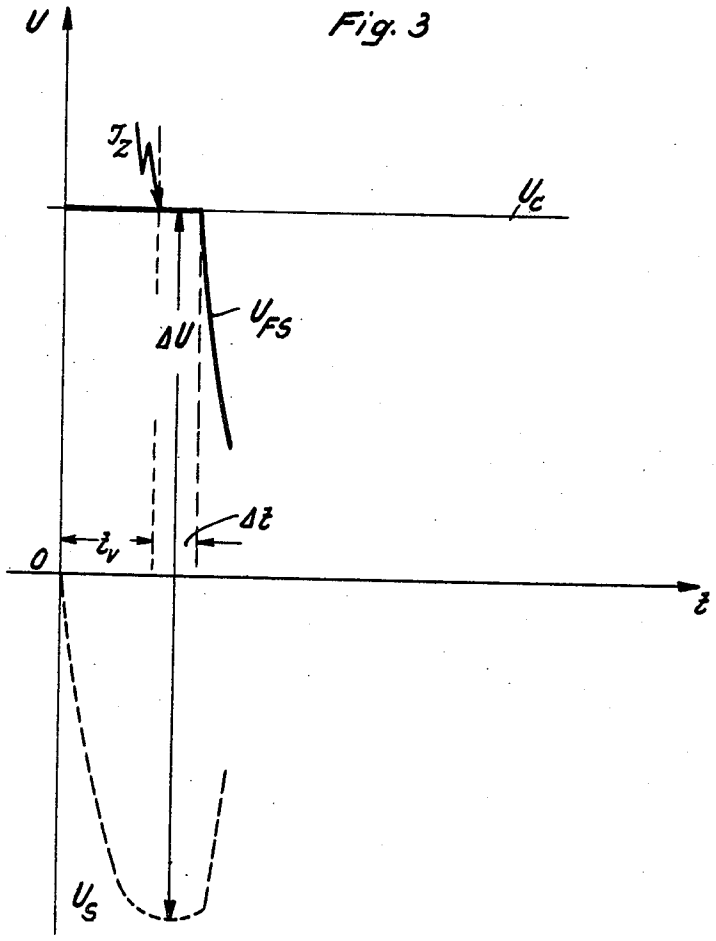


Fig. 3



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Fig. 4

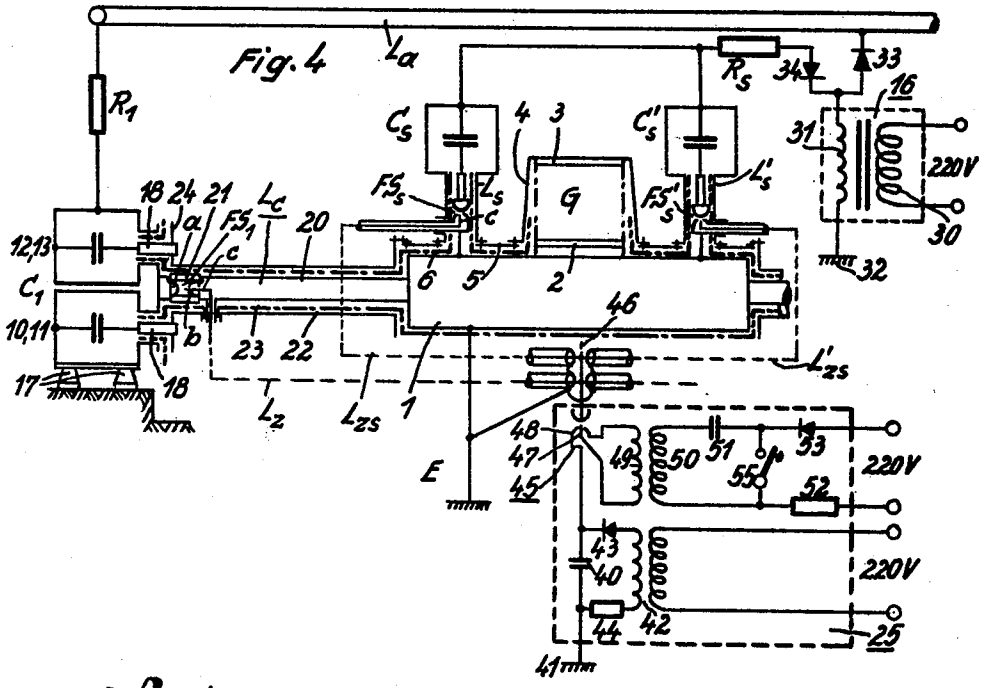
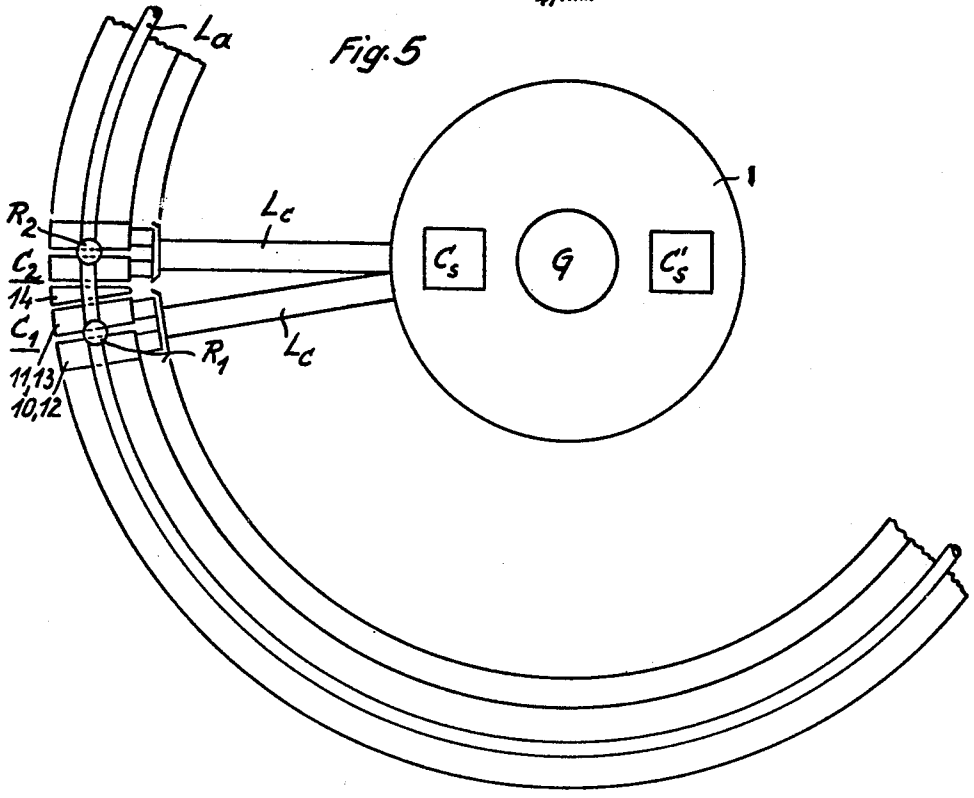


Fig. 5



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SHOCK-CURRENT GENERATOR EMPLOYING MEANS TO EFFECT SIMULTANEOUS DISCHARGE OF PLURAL STORAGE DEVICES

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10 Claims. (Cl. 328—67)

Our invention relates to a generator for producing electric current pulses of extreme intensity and extremely steep wave shape. Such generators are applicable for testing purposes, investigation of plasma discharges and nuclear fusion phenomena.

In order to obtain the desired high current amplitudes, such shock generators, as a rule, are provided with a multiplicity of individual current sources, preferably capacitors, which are simultaneously switched upon the load. The simultaneous switching is effected by connecting the individual current sources, such as the individual capacitors or capacitor groups, with the load terminals through spark-gap devices under control by auxiliary ignition means. The ignition, in most cases, is effected with the aid of an ignition pin mounted in proximity to, but insulated from, one of the electrodes of the spark gap. At the desired switching moment an ignition pulse is supplied to the ignition pins of all spark gaps. This preionizes each spark gap so that it can flash under the effect of the operating voltage impressed between the two gap electrodes. However, even if all spark gaps receive the ignition pulses simultaneously, for example from a common ignition device, it may happen that not all of them will ignite simultaneously in the strict sense so that not all of the capacitors are discharged through the load exactly at the same moment. As a consequence, the amplitude of the current shock as well as its flank steepness are reduced and, in most cases, are not as satisfactory as expectable theoretically.

It is an object of our invention to more reliably achieve an increased accuracy in simultaneousness of ignition and break-through in the spark gaps correlated to the respective capacitors or other current sources in a shock-current generator of the type afore mentioned. Another, related object of our invention is to improve the degree of utilization of the power available from the totality of individual current sources so as to increase the actually effective amplitude of the shock current as well as the steepness of the current-pulse characteristic.

To this end, and in accordance with a feature of our invention, we provide a shock-current generator of the above-mentioned type with an auxiliary voltage source, which, when the individual current sources are switched on by ignition of the respective spark gaps, is connected to the load to impress thereupon an auxiliary voltage poled in opposition to the voltage polarity of the current sources. As will be explained, the provision and operation of such an auxiliary voltage source increases the degree of simultaneousness at which the totality of current sources are made effective so that a current surge of higher intensity and greater curve steepness is obtained. This is particularly advantageous in plants for research and testing work concerning the production of the so-called pinch effect in plasma, or for the like investigations relating to nuclear fusion phenomena, where an extremely fast rise of the current at the rate of 10^{12} to 10^{15} amps/second is desirable.

Our invention is based upon the following recognition. Since the spark gaps for switching the charged capacitors or other current sources upon the load must of necessity, possess a break-through voltage greater than the voltage

of the current sources, the spark gaps do not immediately respond to the ignition effected by the ignition devices. The break-through rather takes place with a discharge delay in the order of 10^{-6} to 10^{-8} second. This delay is not constant but differs among the respective spark gaps. It is virtually inevitable that one of the spark gaps will break through earlier than all others. When the current source whose spark gap is thus switched-on ahead of the others, becomes discharged through the load, the negligibly small resistance of the conductors between current source and load causes substantially the entire voltage of the current source to be impressed upon the load. This has the consequence that the voltage at the other spark gaps of the parallel-connected current sources is instantaneously reduced to the zero value. Hence, the spark gaps of the other parallel-connected current sources cannot fire. The firing of these spark gaps takes place only after the voltage imposed upon the load by the first-switching current source has decayed to such an extent that again a higher voltage occurs across the other spark gaps. In many cases, however, only one of the other spark gaps will then ignite first. Consequently, only a portion of the other current sources will next become discharged. The performance therefore progresses in cascade or chain fashion.

The provision of an auxiliary voltage source according to the invention as briefly outlined above, has the effect that the first discharging current source does not impose too high a voltage upon the load. The auxiliary voltage source of opposed polarity keeps the voltage at the load so low that a voltage sufficient for ignition remains available at the spark gaps of the other current sources. Although this has the consequence that the power of the first-switching current source is partially lost for the intended purpose, such loss is negligible because all other spark gaps can now ignite without delay, thus securing a considerably higher rate of current rise and current amplitude than attainable with the shock-current generators heretofore available.

According to another feature of our invention, the just-mentioned power loss of the first-switching source can be kept extremely slight by using as auxiliary voltage source a capacitor which is charged to a voltage higher than that of the current sources. In this case, a very small capacitance value for the auxiliary voltage source is sufficient, which can take up only an extremely slight fraction of the energy available in the current sources.

According to still another feature, the auxiliary voltage source is composed of a plurality of capacitors arranged symmetrically with respect to the load. This is particularly advantageous in cases where only little space is available at the load so that a large capacitor cannot readily be accommodated. The symmetrical arrangement of voltage-supplying auxiliary capacitors is also of advantage in many cases because the discharge phenomena in such shock-current generators occur with such extreme rapidity that the travelling-wave periods of the conductors must be taken into account.

According to another, preferred feature of our invention, the auxiliary voltage source is connected to the load in such time relation to the firing of the above-mentioned spark gaps that the auxiliary voltage becomes effective just prior to the ignition of the spark gaps. As a result, a high voltage is impressed across the spark gaps before any of them is ignited to effect discharge of the appertaining current source.

For example, the provision of an auxiliary voltage source having a voltage equal to that of the current sources, increases the shock factor of the switching spark gaps from less than the value 1 up to about 2. The "shock factor" is the ratio of the voltage impressed upon

a spark gap at the ignition moment relative to the static break-through voltage of the spark gap. This increase in shock factor results in a considerable shortening of the discharge delay of the spark gaps. The shortening of the discharge delay, i.e. the time elapsing between the application of the voltage and the breakthrough of the spark gaps, in turn results in improving the degree of simultaneousness of ignition in all spark gaps of the respective current sources.

Preferably, the difference in time between the activation of the voltage source and the ignition of the spark gaps is so chosen that the source voltage appears across the spark gaps as accurately as possible at the same moment at which the ignition pulse required for firing the spark gap reaches the ignition pins. With the usual dimensions of such shock-current generators, this time interval amounts to approximately 10^{-8} second. The auxiliary voltage should not become effective after the ignition pulse has arrived at the spark gaps. On the other hand, the auxiliary voltage should not become effective too early before the arrival of the ignition pulse because then, under certain circumstances, the spark gaps may become ignited by the effect of the auxiliary voltage alone. Since the shock factor is still relatively small (approximately 2), such premature ignition would be accompanied by excessive stray between the ignition moments of the respective spark gaps and thus would interfere with the desired high degree of simultaneousness.

According to still another feature of our invention it is preferable to switch the auxiliary voltage source, like the current sources, by means of a spark gap under control by an auxiliary ignition device. In this case, the spark gap of the auxiliary voltage source and the spark gaps of the respective current sources can be ignited under control by a common ignition device. The desired timing in such an apparatus can be obtained in a simple and accurately adjustable manner by providing for different travelling-wave periods of the conductors that supply the ignition pulses to the individual spark gaps.

The simultaneousness of ignition in shock-current generators according to the invention can be further improved by having two adjacent spark gaps of respective current sources interconnected by a conductor, possessing a travelling-wave period about equal to the average discharge delay of about 10^{-8} second, for example. Such a discharge delay in the order of 10^{-8} second applies to a spark gap with auxiliary ignition device for a shock factor of approximately 2. Hence, if adjacent spark gaps are connected with each other by a conductor whose travelling-wave period is in the same order as the discharge delay, any premature discharge of a current source through a spark gap cannot yet reduce the voltage across the adjacent gap within the critical interval of time. Such a conductor with a wave propagation period in the order of 10^{-8} second can readily be provided in shock-current generators where the current sources are mounted remote from the load, for example where the load lies in the center of a circular arrangement of current sources. In such a generator the spark gaps may be arranged directly at the respective current sources so that twice the length of the radial conductor between a current source and the load is available between each two adjacent spark gaps. With the usual dimensions of shock-current generators, this length suffices for obtaining a travelling-wave period of 10^{-8} second.

The foregoing and more specific objects, advantages and features of our invention, said features being set forth with particularity in the claims annexed hereto, will be described in the following with reference to the embodiment of a shock-current generator according to the invention illustrated by way of example on the accompanying drawings, in which:

FIG. 1 is a schematic circuit diagram of the shock generator.

FIGS. 2 and 3 are explanatory graphs relating to the performance of the shock generator.

FIG. 4 shows a schematic, partial front view of the generator, in conjunction with circuit diagrams of component devices; and

FIG. 5 is a partial top view of the shock-current generator.

According to FIG. 1, the shock-current generator comprises a multiplicity of main capacitors C_1, C_2 . . . C_x . . . C_n which constitute respective current sources, and are all connected in parallel. They are charged from a suitable voltage source through respective resistors R_1, R_2 . . . R_x . . . R_n, as will be more fully described with reference to FIG. 4. The load is represented for example by an electronic discharge vessel G for observation of ultra-high temperature or nuclear-fusion phenomena.

Each main capacitor is connected in series with a spark gap device FS_1 . . . FS_n by means of which the capacitors C_1 to C_n are to be simultaneously switched upon the load G. Each spark gap device comprises two electrodes *a* and *b*. Mounted in each electrode *b* and insulated therefrom is an auxiliary ignition pin *c*. Each pin *c* is connected by a lead L_z with an ignition device, described hereinafter, which furnishes an ignition pulse at the switching moment. The ignition pulse causes a breakthrough between the ignition pin *c* and the electrode *b* so that the spark gap between the electrodes *a* and *b* becomes pre-ionized, thus firing each gap for simultaneously discharging the parallel-connected capacitors C_1 to C_n through the load G. One of the two bus conductors L_c is grounded at E.

The shock-current generator is further provided with an auxiliary voltage source which, in the illustrated embodiment, is constituted by an auxiliary capacitor C_s. This capacitor is charged through a resistor R_s by voltage whose polarity is opposed to that of the main capacitors, this being apparent from the plus and minus signs entered in FIG. 1. The auxiliary capacitor C_s is likewise provided with a spark gap device FS_s comprising two electrodes *a*, *b* and an ignition pin *c*. The control lead L_{zs} of the ignition pin is connected to the same ignition device as the control leads L_z of the spark gaps FS_1 to FS_n.

As shown in FIGS. 4 and 5, the load, constituted by the discharge vessel G, is located on a circular carrier **1** in the center of the circular group of capacitors C_1 to C_n, the power electrode **2** of vessel G being directly joined mechanically and electrically with the center structure **1**. The upper electrode **3** is connected to an intermediate conductor piece **4** which forms a hood around the discharge vessel and electrically connects the electrode **3** with an annular conducting disc **5** mounted above the center structure **1** and insulated therefrom at **6**.

The main capacitors C_1 to C_n are arranged in groups of four, with two of the four capacitor units **10** to **13** in each group mounted beside each other (**10**, **11** or **12**, **13**) and two mounted one above the other (**10**, **12** or **11**, **13**). Placed between the capacitor groups are sheet metal boxes **14** filled with sand and having a pointed wedge-like shape so that the circular arrangement apparent from FIG. 5 is obtained. A single charging resistor R_1 to R_n is provided for each of the capacitor groups. Each charging resistor is fastened to a bus conductor L_a of circular shape which extends along and above the capacitor groups. The bus L_a is connected with a source **16** of charging voltage still to be described.

The main capacitors C_1 to C_n are supported by insulators **17**, with the housings of the capacitors under voltage relative to ground. The capacitor housings of each group are connected with the center structure **1** by a tubular conductor **20**. Mounted in the tubular conductor **20** at the end adjacent to the capacitors, is a spark gap device FS. The electrodes *a* and *b* of the spark gap device FS form part of the tubular conductor **20**. They are surrounded by an insulating tube **21**. A second tubu-

lar conductor **22** extends concentrically to the tubular conductor **20** and is separated therefrom by an insulating layer **23**. One end of the tubular conductor **22** is connected through an annular plate **24** with the in-lead bushings **18** of the capacitor group. The other end of tubular conductor **22** is connected to the annular disc **5**. The conductors L_c (FIGS. 1, 2) are thus designed as a coaxial structure constituted by the inner conductor **20** and the outer conductor **22**. The ignition lead L_z (FIGS. 1, 2) which connects the auxiliary ignition pin *c* of the spark gap device FS with ignition device **25** is likewise designed as a coaxial cable.

Two auxiliary capacitors C_s and C'_s are mounted beside the discharge vessel G above the annular disc **5** and are electrically connected between the center structure **1** and the annular disc **5** by a coaxial conductor L_s (FIG. 4) corresponding to the individual leads L_s shown in FIG. 1. The two capacitors C_s and C'_s thus are connected in parallel relation to the discharge vessel G. A spark gap device FS_s is disposed in the coaxial conductor L_s and has its ignition pin *c* connected to the ignition device **25** through a coaxial conductor L_{zs}. The two capacitors C_s and C'_s are located in symmetrical relation to the load G and to the main capacitors C_1 to C_n, and are electrically connected with the voltage source **16** through a charging resistor R_s.

The voltage source **16** comprises a transformer whose low-voltage primary winding **30** is energized from a utility line, for example of 220 volts. The high-voltage secondary winding **31** has one terminal grounded at **32**. The other terminal is connected with two diodes **33, 34** in anti-parallel relation to each other. The rectifier **33** is connected to the charging bus L_a, the rectifier **34** is connected to the charging resistor R_s of the auxiliary capacitors C_s, C'_s. The auxiliary capacitors C_s, C'_s are charged relative to ground potential by a voltage whose polarity is inverse to that of the main capacitor C_1 to C_n.

The ignition device **25** comprises a capacitor **40** which has one electrode grounded at **41**. The capacitor **40** is charged from a transformer **42** through a rectifier **43** and a charging resistor **44**. The low-voltage primary winding of transformer **42** may be energized from a utility line of 220 volts, for example. The other electrode **40** is connected through a spark gap **45** with an ignition bus **46**. The spark gap **45** has an auxiliary ignition pin **41**. Connected between the ignition pin **47** and the electrode **48** which surrounds the pin **47**, is the high-voltage winding **49** of an ignition coil. The low-voltage winding **50** of the ignition coil is connected with a capacitor **51** which is charged through a charging resistor **52** and a rectifier **53** by a voltage of 220 volts, for example. A normally open switch **55** is connected parallel to the low-voltage winding **50** and the capacitor **51**. Closing of switch **55** causes the capacitor **51** to discharge through the winding **50**. This induces in the high-voltage winding **49** a voltage which causes a flash-over between the electrodes **47** and **48** of the spark gap device **45**. This causes firing of the spark gap **45** so that the capacitor **40** is switched onto the ignition bus **46**. The bus **46** passes the ignition pulse through the coaxial conductors L_z or L_{zs} and L'_{zs} to the spark gap of the main capacitors C_1 to C_n as well as to the spark gap of the auxiliary capacitors C_s and C'_s. The jackets of the coaxial conductors are grounded at E.

The conductors L_z and L_{zs} are identical coaxial conductors. Care is taken, however, that the length of the conductor L_z is greater than that of the conductors L_{zs} or L'_{zs}. This has the consequence that the ignition pulse reaches the spark gaps FS_s and FS'_s more rapidly than the spark gaps FS_1 to FS_n.

The performance of the above-described shock-current generator according to the invention will be further explained with reference to FIG. 2 in which the ordinate represents voltage U and the abscissa represents time *t*.

The straight horizontal line U_c represents the charging voltage of the current sources, i.e. of the capacitors C_1 to C_n. The capacitor C_s serving as an auxiliary voltage source has approximately the same voltage U_s but of inverse polarity.

If all capacitors are to be simultaneously switched upon the load G by ignition of the spark gaps FS_1 to FS_n and FS_s, the following will result. Due to the inevitable temporal stray in response of the respective spark gaps, caused by the discharge delay, only one spark gap will be ignited first, for example the spark gap FS_1. Initially therefore, only the capacitor C_1 will discharge through the load G. This causes the load voltage to decline as typified by the curve portion U'_G. Hence, the electrodes *a* and *b* of the other spark gaps FS_1 to FS_n would now be impressed only by the difference voltage

$$U_c - U'_G = \Delta U'$$

Despite any excitation of the ignition pin *c*, this difference voltage would not be sufficient for firing the spark gaps.

However, due to the auxiliary capacitor C_s, provided in accordance with our invention, the voltage U'_G is at first compensated. That is, the discharge of the capacitor C_s, corresponding to the voltage curve shown at U_s by a broken line, causes the load G to be subjected to the voltage U_G indicated in FIG. 2 by a heavy line. As is apparent from FIG. 2, the spark gaps FS_2 to FS_n are now subjected to the considerably higher difference voltage $\Delta U = U_c - U_G$.

The data of the capacitor C_s and the appertaining discharge circuit comprising the leads L_s as shown in FIG. 1 can readily be so chosen that the voltage U_G will remain sufficiently small during a period of time required for firing all spark gaps FS_1 to FS_n. For example, the auxiliary capacitors C_s and C'_s may have a capacitance of $5\mu f$. The capacitance of capacitors C_1 to C_n, however, may be greater, for example 10 μf. The charging voltage is the same for all capacitors, amounting to 30 kv. for example, except that capacitors C_1 to C_n are charged at inverse voltage polarity relating to capacitors C_s and C'_s. The inductivity of the connecting lead L_s, L'_s between the capacitors C_s and C'_s and the discharge vessel G amounts to more than 20 nHenry. This results in a natural frequency of less than 500 kilocycles per second. Therefore, the voltage of the capacitor remains available at the load for a sufficiently long period of time, since the half-wave period is at least $1 \cdot 10^{-6}$ second. If, for example, the spark gaps have a maximum discharge delay of $t_m = 10^{-8}$ second, the voltage U_G during interval t_m remains sufficiently small and hence the voltage

$$\Delta U = U_c - U_G$$

remains sufficiently high for ignition.

In the illustrated embodiment, the voltage U_s of the auxiliary voltage source is just as high as the voltage U_c of the current sources. However, the auxiliary voltage may be given a higher value so that correspondingly smaller capacitance values for capacitor C_s (FIG. 1) are sufficient. The capacitor C_s shown in FIG. 1 may also be composed of a plurality of parallel connected capacitors as is shown in FIG. 4. In the latter case, care must be taken that the discharges of all auxiliary capacitors occur simultaneously. For this purpose, the auxiliary capacitors are symmetrically distributed to prevent the occurrence of different discharge moments due to differently long wave-travelling times in the conductors L_s.

It is particularly favorable if the auxiliary voltage source is connected to the load G prior to igniting the spark gaps FS_1 to FS_n. The performance of such an apparatus is apparent from FIG. 3 representing the voltage at the spark gaps FS_1 to FS_n versus time.

The ignition of the spark gap FS_s occurs at the moment $t=0$. This is an interval t_v earlier than the ignition moments of the spark gaps FS_1 to FS_n. The interval t_v is so chosen that at the moment when the ignition pulse reaches the ignition pins *c* of the spark gaps FS_1 to FS_n, the electrodes *a, b* are subjected to the voltage U_s

whose polarity is opposed to that of the capacitor voltage U_c. As a result, the spark gaps FS_1 to FS_n are impressed by the total voltage $\Delta U = U_c + U_s$. Even if the voltage U_s is equal to the voltage U_c, a shock factor of approximately 2 is obtained instead of the heretofore obtainable shock factor below the unity value. By virtue of the increased shock factor, a considerable shortening of the discharge delay is obtained with a corresponding improvement in simultaneousness of ignition. The ionization of the spark gaps FS_1 to FS_n, caused by the ignition pulse I_z, is accompanied by a discharge delay $\Delta t = 10^{-9}$ second of such a short duration that the requirement for simultaneous ignition is more perfectly satisfied than heretofore possible. The shock current closely approaches the rate of current rise and amplitude of the theoretically calculated sum values. By increasing the charging voltage U_s beyond the value U_c, the degree of simultaneousness can be further improved. It is essential that this does not require an appreciable additional power supply. After igniting the spark gaps FS_1 to FS_n, the voltage U_s drops down to the arc voltage of the load.

The time interval t_v, in the shock-current generators heretofore available, amounts to approximately 10^{-7} second. This time difference can be attained, for example, by having the spark gaps FS_s and the spark gaps FS_1 to FS_n ignited by the same ignition device and giving the ignition conductors L_z leading to the spark gaps FS_1 to FS_n a higher travelling-wave period than the ignition lead L_{zs} of the spark gap FS_s. For this purpose, it is generally preferable to use conductors of the same design, differing from each other only in length. However, the different travelling-wave period can also be obtained by using respective conductors of different designs.

In plants where the main capacitors C_1 to C_n cannot be installed directly at the load G but must be located at some distance therefrom, it is further of advantage to mount the spark gaps FS_1 to FS_n directly at the current sources, namely at the main capacitors C_1 to C_n as illustrated in FIG. 4. In contrast to the schematic representation in FIG. 1, the spark gaps then are interconnected by the coaxial connecting lines L_c extending between the capacitors C_1 to C_n and the load G. For example, the line L_c between the capacitors C_1 to C_n and the center structure **1** may have a length of 0.75 m. The tube **23** in this case may have an outer diameter of 10 cm., and wall thickness of 1 mm., the thickness of the insulation between tubes **22** and **23** being 1 to 2 mm. Such a coaxial line has a travelling-wave velocity of about one half the speed of light, or 150,000 km., per second. Since twice the length of the line L_c extends between two spark gaps FS_1 to FS_n, if the spark gaps as shown in FIG. 4 are located in proximity of the respective capacitors C_1 to C_n, the ignition of one spark gap can make itself felt at the other spark gaps only after the wave has travelled a distance of $2 \times 0.75 = 1.5$ m. length of conductor line. Hence, with a travelling velocity of 1.5 m./10^{-8} second, an interval of 1.10^{-8} second will lapse before the ignition of one gap will affect the electrode voltage across another gap. As explained, this has the advantage that a premature discharge of a current source can affect adjacent spark gaps only after the just-mentioned interval of time. Consequently, the other spark gaps, at the moment of premature switching in a spark gap, remain at first subjected to the desired voltage ΔU during the interval of time required for the travelling wave to pass from one to another spark gap. In this manner, the degree of simultaneousness in ignition is further improved. The travelling time of the line between adjacent spark gaps must be greater for this purpose than the maximum discharge delay at the spark gaps FS_1 to FS_n for a given shock factor.

While in the above-described embodiments capacitors are used as current sources and voltage sources, the invention is likewise of advantage in shock current generating plants equipped with other types of current and voltage sources, for example, with synchronously operating alternating-current shock generators which form the current sources to be switched simultaneously. Also suitable as source of auxiliary voltage are batteries, for example. In this case a rapidly acting switch may be used for connecting the voltage to the load only for the desired short interval of time.

It will be obvious to those skilled in the art, upon a study of this disclosure, that such and other modifications of our invention can readily be made without departing from the essential features of our invention and within the scope of the claims annexed hereto.

We claim:

1. A shock-current generator, comprising a multiplicity of surge-current sources, load terminals to which said current sources are connected in parallel relation to each other with the same respective voltage polarities, normally open current control means having respective spark gaps interposed between said respective current sources and said terminals and having ignition means for simultaneously igniting said spark gaps to simultaneously switch said current sources onto said load terminals to jointly produce a shock current when a load is connected to said terminals, a voltage source connected across said load terminals, said control means comprising switching means interposed between said voltage source and said terminals for impressing the voltage of said voltage source across said terminals when said current sources are being switched onto said terminals, said voltage source having at said terminals a voltage polarity opposed to that of said current sources.

2. A shock-current generator, comprising a multiplicity of main capacitors and means for charging them to serve as surge-current sources, load terminals to which said main capacitors are connected in parallel relation to each other with the same respective voltage polarities, normally open current control means having respective spark gaps interposed between said respective main capacitors and said terminals and having ignition means for simultaneously igniting said spark gaps to discharge said main capacitors for jointly producing an impact current pulse when a load is connected to said terminals, a voltage source connected across said terminals and comprising an auxiliary capacitor, said control means comprising switching means interposed between said auxiliary capacitor and said terminals for impressing the voltage of said auxiliary capacitor across said terminals when said main capacitors are being discharged, said auxiliary capacitors having relative to said terminals a voltage polarity opposed to that of said main capacitors.

3. A shock-current generator, comprising a load, a multiplicity of capacitor means connected to said load in parallel relation to each other to serve as surge-current sources, current supply means for charging said capacitor means, said capacitor means each including a capacitor and spark-gap devices interposed between said load and said respective capacitors, said spark-gap devices having ignition means for causing said spark-gap devices to simultaneously discharge said capacitors through said load for jointly producing a shock current therein, a voltage system connected directly parallel to said load and parallel to said capacitor means and including a voltage source, control means interposed between said voltage source and said load and connected with said ignition means to impress the voltage of said voltage source upon the load in leading time relation to ignition of said spark-gap devices, said voltage source having relative to said load a polarity opposed to the voltage polarity of said capacitors.

4. A shock-current generator, comprising a load constituted by a discharge vessel, a multiplicity of main capacitors connected to said load in parallel relation to each other to serve as surge-current sources, current supply means for charging said main capacitors, spark-gap devices interposed between said load and said respective main capacitors and having ignition means for causing

said spark-gap devices to simultaneously discharge said main capacitors through said load for jointly producing a shock current therein, a voltage source comprising an auxiliary capacitor connected to said load, control means interposed between said auxiliary capacitor and said load and connected with said ignition means to impress the voltage of said auxiliary capacitor upon the load in leading time relation to ignition of said spark-gap devices, the voltage of said auxiliary capacitor when charged being higher than that of said main capacitors and having relative to said load a polarity inverse to that of said main capacitors.

5. In a shock-current generator according to claim 3, said voltage source comprising a plurality of auxiliary capacitors mounted in symmetrical relation to said load and connected in parallel to each other, and circuit means for charging said auxiliary capacitors.

6. In a shock-current generator according to claim 1, said control means having different time constants relative to switching of said current sources and said voltage source respectively so as to render said voltage effective at said load terminals prior to switching of said current sources, the time difference being in the order of 10^{-8} second.

7. A shock-current generator, comprising a load, a multiplicity of main capacitors connected to said load in parallel relation to each other to serve as surge-current sources, current supply means for charging said main capacitors, spark-gap devices interposed between said load and said respective main capacitors and having ignition means for causing said spark-gap devices to simultaneously discharge said main capacitors through said load for jointly producing a shock current therein, a voltage source comprising auxiliary capacitor means connected in parallel to said load, another spark-gap device interposed between said auxiliary capacitor means and said load and having ignition means for causing said auxiliary capacitor means to impress a voltage upon said load, the voltage of said auxiliary capacitor means having a polarity opposed to that of said main capacitors, an ignition pulse transmitter common to all of said spark-gap devices, and conductors connecting said transmitter with said respective ignition means and having respectively different wave-travelling periods whereby the pulse issuing from said transmitter reaches said spark-gap device for said auxiliary capacitor means earlier than the other spark-gap devices.

8. A shock-current generator according to claim 1, comprising conductor means connecting said spark gaps in parallel relation to each other, said conductor means having between adjacent spark gaps a wave-travel constant in the order of 10^{-8} second.

9. In a shock-current generator according to claim 3, said capacitors being spaced from said load, said spark-gap devices being disposed in proximity of said respective capacitors, and conductor means connecting said spark-gap devices with said load, said conductor means having between adjacent spark-gap devices a wave-travel constant in the order of 10^{-8} second.

10. A shock-current generator, comprising a centrally arranged load, a circular group of main capacitors radially spaced from said load and peripherally distributed about said load, current supply means for charging said capacitors, spark-gap devices serially interposed between said load and said respective capacitors and having ignition means for causing said spark-gap devices to simultaneously discharge said capacitors through said load for jointly producing a shock current therein, said spark-gap devices being located in proximity to said respective main capacitors, coaxial conductor means extending radially between said respective spark-gap devices and said load and electrically connecting said main capacitors in parallel relation to each other across said load, a source of voltage comprising a plurality of auxiliary capacitors mounted centrally of said circular group and connected in parallel to each other across said load, the voltage of said auxiliary capacitors having a polarity opposed to the voltage polarity of said main capacitors, additional spark-gap devices serially interposed between said load and said auxiliary capacitors respectively and having ignition means for applying said voltage to said load, an ignition pulse transmitter, conductor means connecting said transmitter with said ignition means of all of said spark-gap devices, said conductor means having between said transmitter and said spark-gap devices of said auxiliary capacitors a wave-travel time constant shorter than between said transmitter and said other spark-gap devices, the difference being in the order of 10^{-8} second, and said coaxial conductor means having between peripherally adjacent main capacitors a wave-travel time constant in said same order of magnitude.

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