Sept. 2, 1941. W. H. BOLDINGH 2,254,836

IMPULSE VOLTAGE APPARATUS

Filed June 20, 1939 2 Sheets-Sheet 1

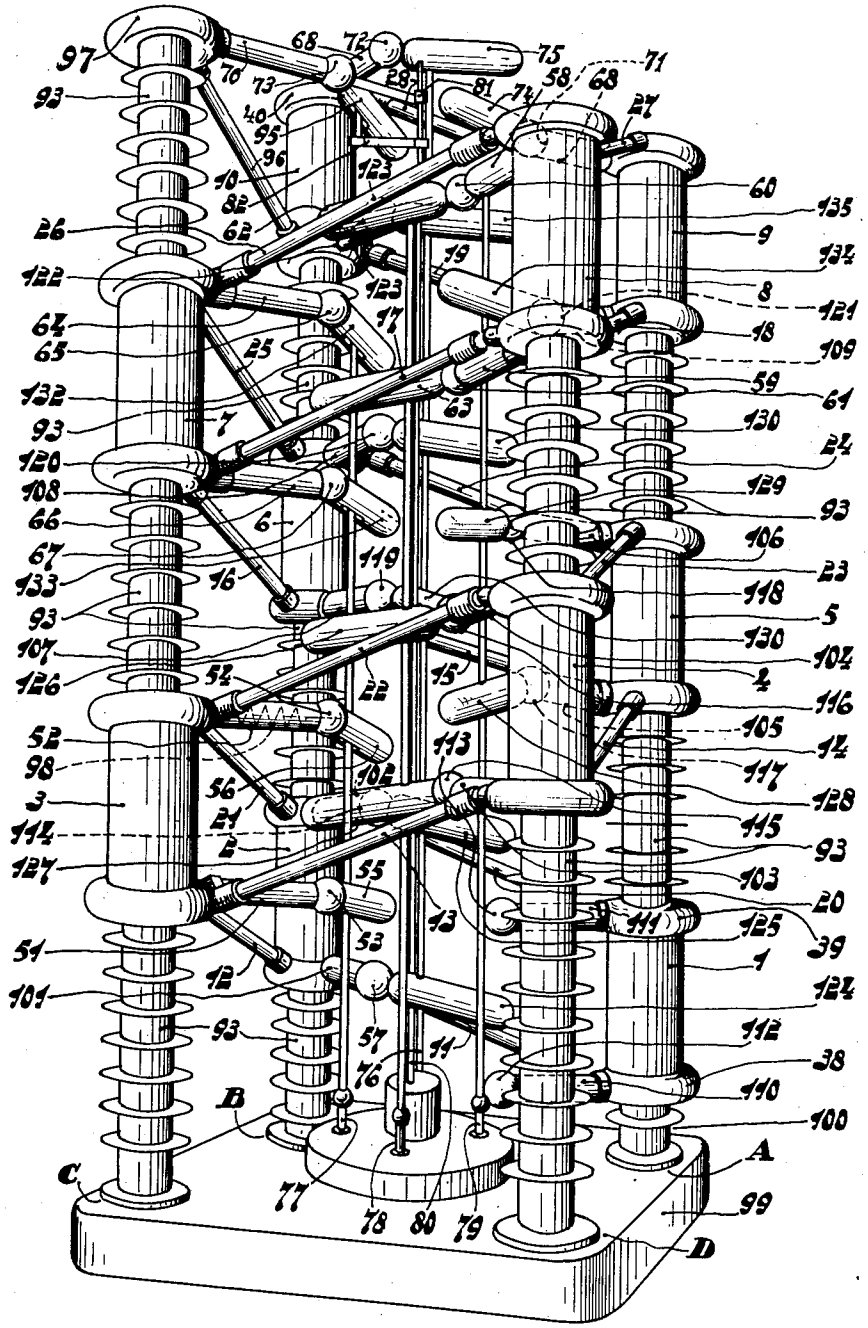


Fig. 1.

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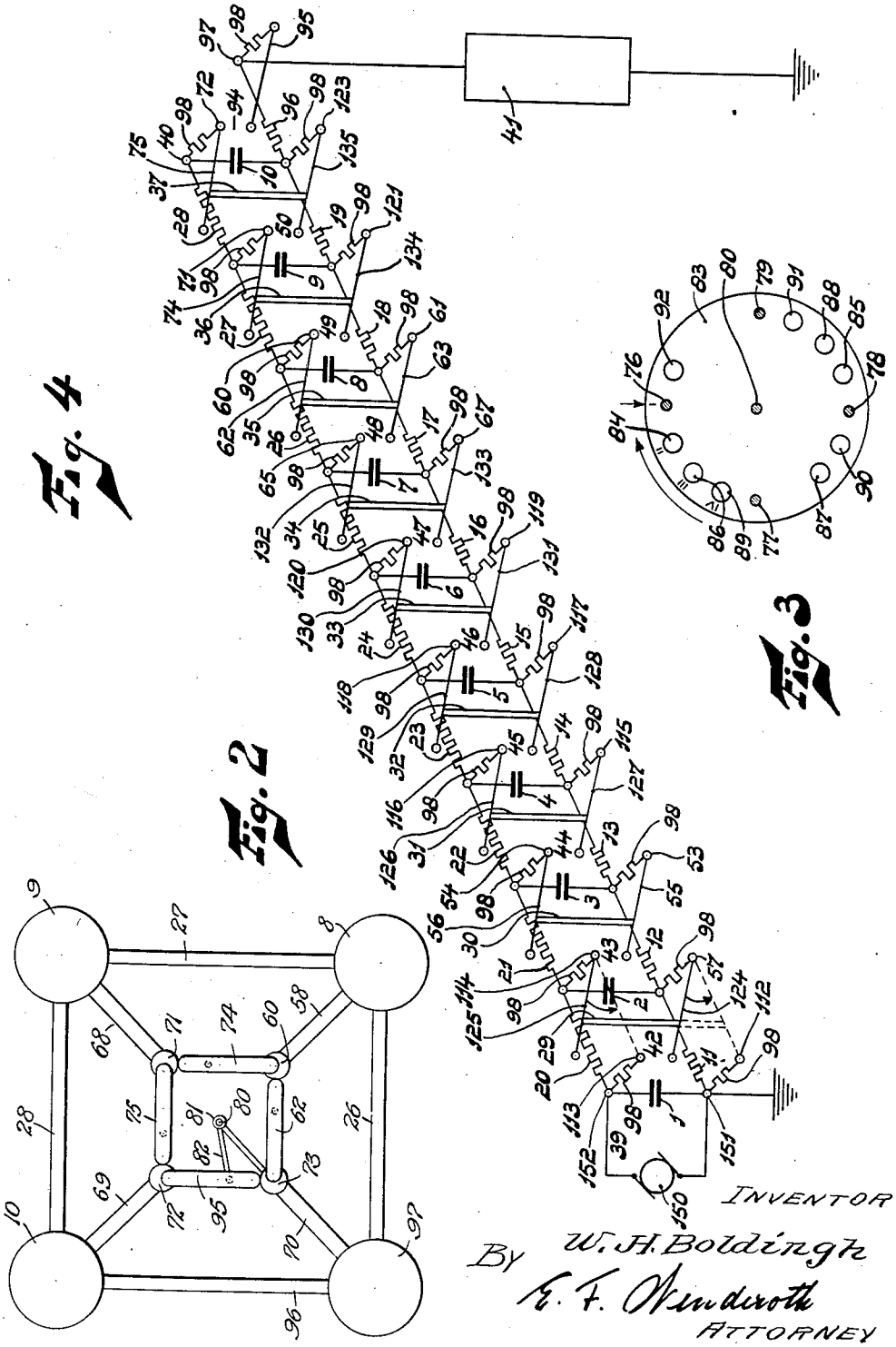


Fig. 4

Fig. 3

Fig. 2

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Patented Sept. 2, 1941

2,254,836

UNITED STATES PATENT OFFICE

2,254,836

IMPULSE VOLTAGE APPARATUS

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Application June 20, 1939, Serial No. 280,218
In Germany June 22, 1938

14 Claims. (Cl. 171—97)

My invention relates to an impulse voltage apparatus.

As is well-known, an apparatus of this type comprises a plurality of condensers connected in parallel through resistances and connected in series through spark gaps. The condensers are charged from a source of direct current, and at a determined voltage the spark gaps break down and the charges of the condensers flow away through a resistance. The voltage can be regulated by varying the spacing of the spark-gap electrodes. However, if the voltage selected is lower, i. e. short spark gaps, the available energy also is lower.

I have found that, irrespective of the value of the voltage, it is usually desirable in practice to have a substantially constant energy, and the main object of the invention is to provide an apparatus in which the voltage may be varied in stages without any variation of the available energy.

The apparatus according to the invention comprises bi-polar high-voltage change-over switches with which a few condensers may be connected either in parallel to form a group, or connected in series through spark gaps. The resistances for the charging of the condensers remain connected in the usual manner to the condensers.

If there are, for example, twelve condensers in the apparatus, and if the charging voltage amounts to 100 kv., it is possible, apart from the loss of voltage in the spark gaps and the damping resistances, to set up a voltage of 1200 kv. when all the condensers are located in series through the spark gaps. In such a case I may provide, for example, six series-parallel switches with which the twelve condensers may be divided into six groups each comprising two condensers connected in parallel. Because of the parallel connection of the condensers, the voltage is reduced to half its value, but the available number of watt-seconds remains constant. These six switches may be mechanically connected to one another in such a manner that the change-over from 1200 to 600 kv. can be effected in one switching operation.

It is also possible with the aid of eight change-over switches, to divide the condensers into four groups each comprising three condensers or with the aid of nine switches to divide the condensers into three groups each comprising four condensers, so that it is possible to reduce the voltage to 400 and 300 kv. respectively. By using ten switches it is possible to connect six condensers in parallel to thereby obtain a voltage of 200 kv. Finally, it is possible, when using eleven switches, to connect all twelve condensers in parallel and to utilize the same energy with 100 kv.

According to another embodiment of the invention, I assemble condensers in columns in which they are separated from one another by insulators, and arrange these columns at the corners of a regular polygon. Assuming that the number of columns is n (n being greater than 2) one column would comprise the 1*st* and the $n+1th$ condenser and, as the case may be, the $2n+1th$ condenser, etc. The second column would comprise the 2nd condenser of the system, the $n+2th$, the $2n+2th$, etc. The third column would comprise the condensers numbered 3, $n+3$, $2n+3$, etc., and the fourth column would comprise the condensers 4, $n+4$, $2n+4$ . . . , etc. In such an arrangement the switches of condensers 1 and $n+1$, 2 and $n+2$, 3 and $n+3$, etc., can be easily mechanically interconnected because these condensers would be arranged in a straight line one above the other.

To obtain a satisfactory spatial potential distribution and a practical arrangement, I prefer to so arrange the condensers that each condenser is the same distance above the condenser of the preceding number in the series. For example, in the case of n columns, the insulator which separates the 1*st* and the $n+1th$ condenser and the 1*st* condenser itself would together have a length of d cms., whereas the second condenser should be arranged d/n cms. higher, the third condenser $2d/n$ cms. higher, the fourth condenser $3d/n$ cms. higher than the first condenser, etc.

To give the switches the simplest possible construction they may be secured to arms which extend radially towards the middle of the apparatus. In this case each arm carries a fixed switching member and a movable switching member, the former co-operating with the one neighbouring condenser and the latter with the other. A damping resistance may be arranged within each arm, and such an arrangement has the additional advantage that when two, or more than two, condensers are connected in parallel the corresponding damping resistances are automatically also connected in parallel.

In order that the invention may be clearly understood and readily carried into effect I shall describe the same in more detail with reference to the accompanying drawings.

Figure 1 is a front view in perspective of a

voltage impulse apparatus according to the invention,

Figure 2 is a top view of the apparatus of Figure 1,

Figure 3 is a diagrammatical view of a portion of a device for actuating the high-voltage change-over switches of Figure 1, and

Figure 4 is a schematic wiring diagram of the apparatus shown in Figure 1.

The apparatus shown on Figure 1 comprises a suitable base 99 at the corners of which are arranged four columns A, B, C, and D. Column A comprises three condensers 1, 5, and 9 separated by insulators 93, column B comprises three condensers 2, 6, and 10 separated by insulators 93, column C comprises two condensers 3 and 7 separated by insulators 93, and column D comprises two condensers 4 and 8 separated by an insulator 93. Insulators 93 are also provided at each end of column C and at the bottom of columns B, C and D, and an insulator 100 is provided at the bottom of column A. It will be noted that each of the condensers 1 to 10 is located the same distance above the condenser having the next lowest reference numeral.

Condensers 1 to 10 are connected in parallel by charging resistances 11 to 28 inclusive. More particularly and as shown in Figure 4, the terminals of condenser 1 are connected to the terminals of condenser 2 by the resistances 11 and 20, the terminals of condenser 2 are connected to the terminals of condenser 3 by resistances 12 and 21, etc. As shown in Figure 1 the ends of the condensers 1 to 10 are provided with bosses to which the resistances 11 to 28 are connected in order to avoid corona phenomena. The bosses on condenser 1 are indicated by reference numerals 38 and 39.

As shown on Figure 1, each of the condensers 1 to 10 carries two stationary arms each provided at its end with a ball which acts as a stationary contact and to which is rotatably secured a movable switching member. For example, the lower end of condenser 3 supports a stationary arm 51 provided with a ball-shaped contact 53 to which is rotatably secured a switching member 55, and the upper end of this condenser carries a stationary arm 52 provided with a ball-shaped contact 54 to which is rotatably secured a switching member 56. In a similar manner condensers 1, 2, 4, 5, 6, 7, 8, 9, and 10 are provided with stationary arms 110—111, 101—102, 103—104, 105—106, 107—108, 66—64, 59—58, 109—68 and 122—69 respectively provided with ball-shaped contacts 112—113, 57—114, 115—116, 117—118, 119—120, 67—65, 61—60, 121—71, and 123—72 respectively. Rotatably mounted on the ends of the stationary arms of condensers 2, 4, 5, 6, 7, 8, 9, and 10 are switching members 124—125, 127—126, 128—129, 131—130, 133—132, 63—62, 134—74, and 135—75 respectively.

In Figure 4 the switching arms and ball-shaped contacts are shown schematically and are indicated by the reference numerals used on Figure 1.

When the switching members 55 and 56 are raised, the end of member 55 is placed in the vicinity of the ball-shaped contact 114 with the result that condensers 2 and 3 are placed in series by the spark gap so formed. By regulating the length of this spark gap it is possible to adjust the voltage at which the break-down of the gap will occur. When members 55 and 56 are moved downwardly the ends thereof effect an electrical connection with the ball contacts 57 and 114 respectively to thereby place condensers 2 and 3 in parallel. In a similar manner the ends of switching members 62 and 63 of condenser 8 form the poles of a series-parallel switch and when these members are raised the end of member 63 comes into the vicinity of the ball-shaped contact 65 of condenser 7 and a spark is formed between the same; switching member 62 being inoperative in this position. When members 62 and 63 are lowered, ball contact 61 is connected by switching member 63 to ball contact 67 and ball contact 60 is connected to ball contact 65 with the result that condensers 7 and 8 are connected in parallel.

In this manner it is possible to connect, for example, the condensers of columns A and B and the condensers of columns C and D simultaneously in series or in parallel. With the remaining switch arms it is possible to connect the condensers 5 and 9 of column A, and to connect condensers 3 and 7 of column C in series or parallel with the condensers 2 and 6 of column B.

As shown more clearly in Figure 2, the upper stationary arms 58, 68, 69, and 70 of the condensers 8, 9, 10, and the high-voltage terminal 97 respectively are provided with ball-shaped contacts 60, 71, 72, and 73 respectively to which are rotatably secured movable switching members 62, 74, 75, and 95 respectively.

As shown in Figure 1 the switching members are actuated by rods 76, 77, 78, 79, and 80 of insulating material. More particularly, rod 76 actuates the switching members 124—125, 131—130, and 135—75, rod 77 actuates the switching members 55—56 and 133—132, rod 78 actuates the switching members 127—126 and 63—62, and rod 79 actuates the switching members 128—129 and 134—74. The central rod 80 serves to actuate only the arm 95.

As shown in Figure 2 a guide 81 for rod 80 is secured to the stationary arm 70, and a rod 82 connects arm 95 to rod 80.

Rods 76, 77, 78, 79, and 80 are actuated in such a manner that the lengths of all the spark gaps between the ball contacts and the ends of the switching members can be changed in a similar manner and in one operation. A suitable mechanism for obtaining this result is diagrammatically illustrated in Figure 3, which mechanism is assumed to apply to an installation comprising a number of condensers which is a multiple of four, for example, twelve, i. e., an installation comprising four columns each having the same number of condensers.

As shown in Figure 3, the lower ends of rods 76, 77, 78, 79, and 80 bear upon the upper surface of a disc 83 which is located within the base 99 of Figure 1. Disc 83 is adapted to be raised or lowered in a direction perpendicular to the plane of the drawing in Figure 3, for instance by an electric motor (not shown). This disc is also adapted to be rotated about its center so as to be placed in one of four positions indicated by I, II, III, and IV. When the disc is in its lower position, the rods 76, 77, 78, 79, and 80 are clear of the upper surface and the switching members of Figure 1 are supported by the ball-shaped contacts and thus are in contact therewith. The disc 83 is also provided with nine holes 84 to 92 inclusive arranged in a circle and of a larger diameter than rods 76 to 79.

With disc 83 in position I as shown, all of the rods 76 to 80 will be raised when the disc is raised. When the disc 83 is rotated clockwise into position II, the holes 84 and 85 will lie beneath rods

76 and 78 respectively with the result that when the disc is raised only rods 77, 79, and 80 will be raised. As a result condensers 1 and 2, 3 and 4, 5 and 6, 7 and 8, and 9 and 10, and as the case may be the eleventh and twelfth condenser, will remain connected in parallel, whereas regulatable spark gaps are formed between condensers 2 and 3, 4 and 5, 6 and 7, and 8 and 9, and as the case may be 10 and the eleventh condenser and at the high-voltage terminal (in the Figure 4 between ball-shaped contact 72 of condenser 10 and terminal 97).

When disc 83 is placed in position III, holes 86, 87, and 88 will be beneath rods 76, 77, and 78 respectively with the result that these rods will not be raised when the disc is raised. This position is only important for the case in which the installation comprises a number of condensers equal to a multiple of four. In this position only rods 79 and 80 will be raised when the disc 83 is raised with the result that the condensers will be divided into groups of four parallel connected condensers.

When disc 83 is placed in position IV, holes 89, 90, 91, and 92 will be beneath rods 76, 77, 78 and 79 respectively with the result that when the disc is raised only rod 80, and thus switching member 95 will be raised. In such a position all the condensers will be connected in parallel and the voltage will be adjusted to the lowest stage.

An apparatus of the type described above has a high mechanical rigidity because it has a unitary structure. Furthermore, the weight of the apparatus as well as the volume thereof and the floor space required are very small.

The operation of the apparatus will be described in more detail with reference to Figure 4, which is a schematic diagram of the apparatus shown in the preceeding figures.

The condensers 1 to 10 may have a capacity of 0.125 μF., each of the resistances 11 to 19 may have a value of 500 ohms, and each of the resistances 20 to 28 may have a value of 10,000 ohms.

As shown in Figure 4 the two movable arms associated with each of the condensers 2 to 10 are connected together to form nine series-parallel switches 29—37. A suitable D. C. source of supply voltage 150 has its terminals connected to points 151 and 152 which correspond to the bosses 38 and 39 respectfully of condenser 1 (see Figure 1). Point 151 is preferably grounded as shown, and a suitable load 41 is connected between the high-voltage terminal 97 and ground. The high-voltage terminal 40 of condenser 10 is connected to ground through a spark gap 94 and the series connection of resistances 11 to 19 inclusive and 96.

It should be noted that each of the movable switching members are electrically connected to the corresponding terminals of the condensers through a damping resistance 98, for example, a 25 ohm resistance. In Figure 1 these resistances are located within the stationary arms to which the switching members are rotatably secured as indicated for arm 52.

When the installation is placed into operation, the condensers are simultaneously charged through resistances 11 to 28 inclusive. Before they have reached the final voltage the spark gaps 42—50 and 94 break down. The condensers are now connected in series and their voltages are additive. The nominal value of the high voltage is 10 V if V is the voltage of the supply source 150.

When switches 29, 31, 33, 35 and 37 are shifted, condensers 1 and 2, 3 and 4, 5 and 6, 7 and 8, and 9 and 10, together with their damping resistances 98, are connected in parallel and consequently six groups each consisting of two condensers connected in parallel are formed, these groups being located in series via the spark gaps 43, 45, 47 and 49. The nominal value of the voltage is now 5 V volts. In this position the switches occupy the position indicated in dotted lines for switch 29.

When, in addition, the switches 30, 32, 34 and 36 are shifted, all the condensers are connected in parallel and the voltage amounts to V volts. In each of these three cases the energy is, however, 5 CV^2 in which C is the capacity of each of the condensers.

There is also provided a switch 95 by means of which, if each of the switches 29—37 takes its lower position, the high-voltage terminal 97 may be grounded through switch arms 135, 134, 63, 133, 131, 128, 127, 55 and 124. Otherwise this terminal is permanently connected through resistances 96 and 11 to 19 to the ground.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, because obvious modifications will readily occur to a person skilled in the art.

What I claim is:

1. An impulse voltage apparatus comprising a plurality of condensers, resistances connecting said condensers in parallel, said condensers being connected in series through spark gaps, and means to remove some of said spark gaps and shunt the resistances connected thereto to thereby divide the condensers into a plurality of groups each comprising the same number of condensers, the condensers of each group being connected in parallel by the non-shunted resistances and in series by the remaining spark gaps.

2. An impulse voltage apparatus comprising a plurality of condensers, resistances connecting said condensers in parallel, switching members forming spark gaps connecting said condensers in series, and means including said switching members to simultaneously remove said spark gaps and shunt the resistances.

3. An impulse voltage apparatus comprising a plurality of condensers, resistances connecting said condensers in parallel, switching members forming spark gaps connecting groups of said condensers in series, and a two-position switch between each two adjacent condensers of each group, said switch in one position establishing a spark gap connecting the adjacent condensers in series and in its second position shunting the resistances connected between the adjacent condensers.

4. An impulse voltage apparatus comprising a plurality of condensers, resistances connecting said condensers in parallel, and a two-position switch between each two adjacent condensers, each switch in one position establishing a spark gap connecting the adjacent condensers in series and in its second position shunting the resistances connected between the adjacent condensers.

5. An impulse voltage apparatus comprising a plurality of condensers arranged in n columns each located at the corner of a polygon, n being more than two, a plurality of resistances connecting said condensers in parallel, insulators separating the condensers of each column, the 1*st*, $n+1$*st*, the $2n+1$*st*, etc. condensers being

arranged in one column, the 2*nd*, *n*+2*nd*, 2*n*+2*nd*, etc. condensers being arranged in a second column and the remaining condensers being arranged in similar manner, switching members adapted to form spark gaps, and switching means including said members to selectively connect all the condensers in parallel or in series through said spark gaps.

6. An impulse voltage apparatus comprising a plurality of condensers arranged in *n* columns each located at the corner of a polygon, *n* being more than two, a plurality of resistances connecting said condensers in parallel, insulators separating the condensers of each column, the 1*st*, *n*+1*st*, the 2*n*+1*st*, etc. condensers being arranged in one column and the remaining condensers being arranged in a similar manner in the other columns, a plurality of two pole double-throw switches connected to the condensers and adapted to form spark gaps, switching means to selectively connect all the condensers in parallel or in series through said spark gaps, said means including said switches and a member mechanically interconnecting the switches associated with the condensers of each column.

7. An impulse voltage apparatus comprising a plurality of condensers arranged in *n* columns each located at the corner of a polygon, *n* being more than two, a plurality of resistances connecting said condensers in parallel, insulators separating the condensers of each column, the 1*st*, *n*+1*st*, the 2*n*+1*st*, etc. condensers being arranged in one column and the remaining condensers being arranged in similar manner, a plurality of double-throw switches each connected to a condenser and movable in vertical planes to form spark gaps, and means to selectively connect all the condensers in parallel or in series through said spark gaps, said means including said switches and actuating members mechanically interconnecting the switches.

8. An impulse voltage apparatus comprising a plurality of condensers arranged in *n* vertical columns each located at the corner of a polygon, *n* being more than two, a plurality of resistances connecting said condensers in parallel, insulators separating the condensers of each column, the 1*st*, *n*+1*st*, the 2*n*+1*st*, etc. condensers being arranged in one column and the remaining condensers being arranged in similar manner, 1 each condenser being located an equal distance above the condenser which preceeds it in the system, switching members adapted to form spark gaps, and means including said members to selectively connect all the condensers in parallel or in series through said spark gaps.

9. An impulse voltage apparatus comprising a plurality of condensers arranged in *n* columns each located at the corner of a polygon, *n* being more than two, a plurality of resistances connecting said condensers in parallel, insulators separating the condensers of each column, the 1*st*, *n*+1*st*, the 2*n*+1*st*, etc, condensers being arranged as one column and the remaining condensers being arranged in similar manner, and means to selectively connect all the condensers in parallel or in series said means comprising a contact member secured to each terminal of the condensers and extending radially, and a movable switching member carried by said contact member and adapted to form a spark gap with the contact member of the adjacent condensers.

10. An impulse voltage apparatus comprising a plurality of condensers arranged in *n* columns each located at the corner of a polygon, *n* being more than two, a plurality of resistances connecting said condensers in parallel, insulators separating the condensers of each column, the 1*st*, *n*+1*st*, the 2*n*+1*st* etc. condensers being arranged as one column and the remaining condensers being arranged in similar manner, means to selectively connect all the condensers in parallel or in series, said means comprising a contact member for each terminal of the condensers and extending radially, and a movable switching member carried by said contact member and adapted to form a spark gap with the contact member of the adjacent condensers, and a damping resistance connection between each contact member and the corresponding condenser.

11. An impulse voltage generator comprising a number of condensers which is a multiple of two, said condensers being arranged in four columns located at the corners of a rectangle, a plurality of resistances connecting said condensers in parallel, means to divide the condensers into groups each comprising two parallel-connected condensers, said means comprising series-parallel switches for interconnecting the condensers of the first and second columns and the condensers of the third and fourth columns.

12. An impulse voltage generator comprising a number of condensers which is a multiple of four, said condensers being arranged in four columns located at the corners of a rectangle, a plurality of resistances connecting said condensers in parallel, means to divide the condensers into groups each comprising four parallel-connected condensers, said means comprising series-parallel switches for interconnecting the condensers of the first and second columns, for interconnecting the condensers of the third and fourth columns, and for interconnecting the condensers of the second and third columns.

13. An impulse voltage generator comprising a number of condensers which is a multiple of two, said condensers being arranged in four columns located at the corners of a rectangle, a plurality of resistances connecting said condensers in parallel, means for connecting all the condensers in parallel comprising series parallel switches for interconnecting the condensers of the second and fourth columns to the condensers of the third and first columns respectively.

14. An impulse voltage apparatus comprising a number of condensers which is a multiple of two, a plurality of resistances connecting said condensers in parallel, said condensers being arranged successively in four columns located at the corners of a rectangle, an inwardly-extending arm at each end of each condenser, a stationary contact on the end of each arm and connected to the corresponding terminal of the condenser, a movable switching member mounted on the top arm of the first condenser and on each arm of the remaining condensers, the switching members of each condenser cooperating with the stationary contacts of the preceding condenser of the parallel connection, and actuating means mechanically interconnecting the movable switching members of the condensers of each column.

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