

F. DESSAUER.
ELECTRICAL TRANSFORMER SYSTEM.
APPLICATION FILED JULY 23, 1918.

1,372,653.

Patented Mar. 22, 1921.

3 SHEETS—SHEET 1.

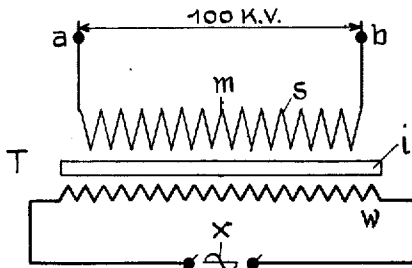


Fig. 1.

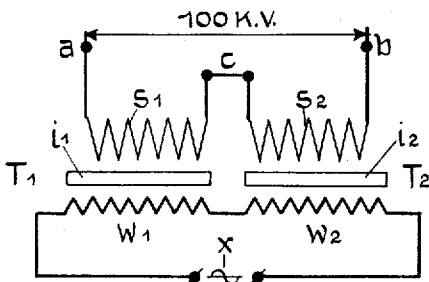
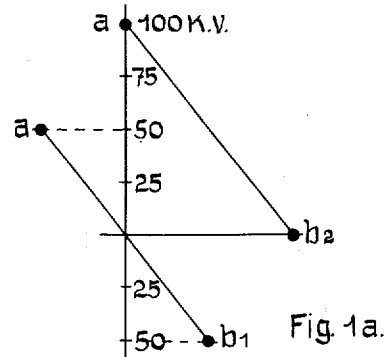


Fig. 2.

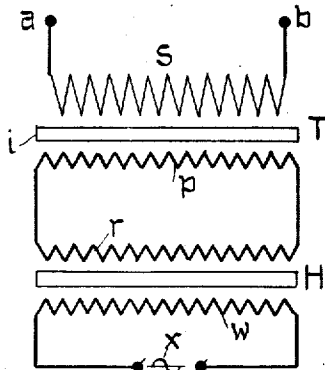
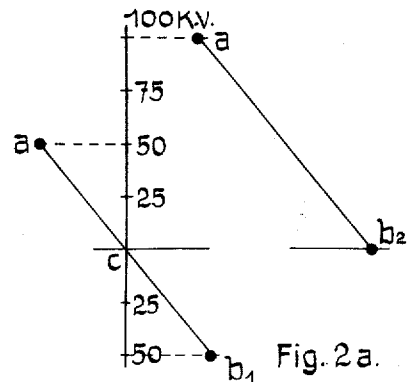


Fig. 3.

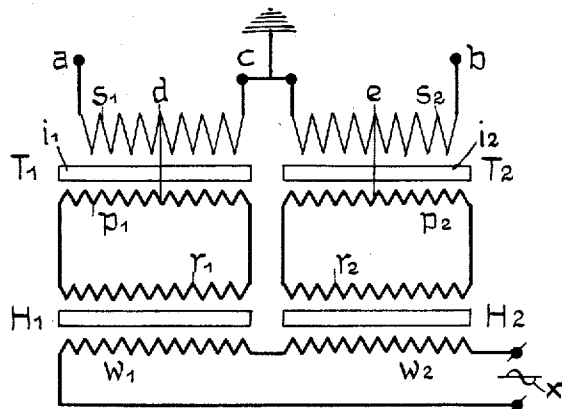
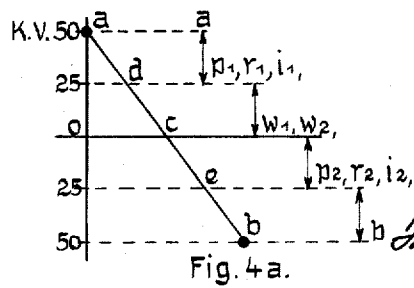


Fig. 4.



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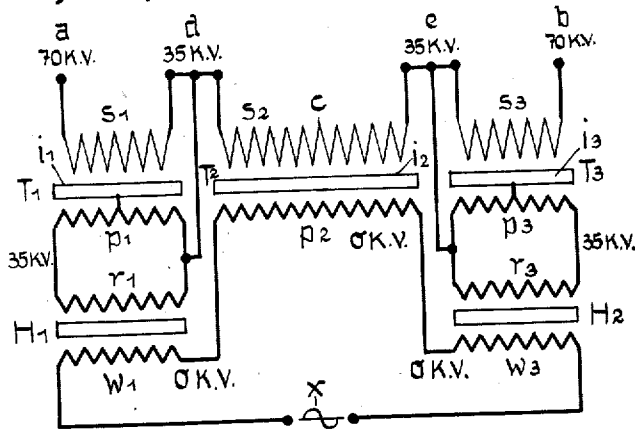


Fig. 5.

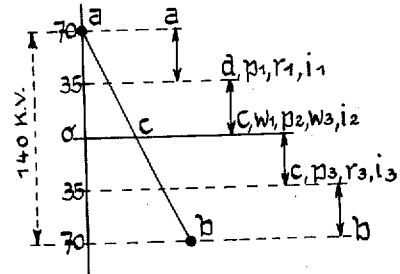


Fig. 5a.

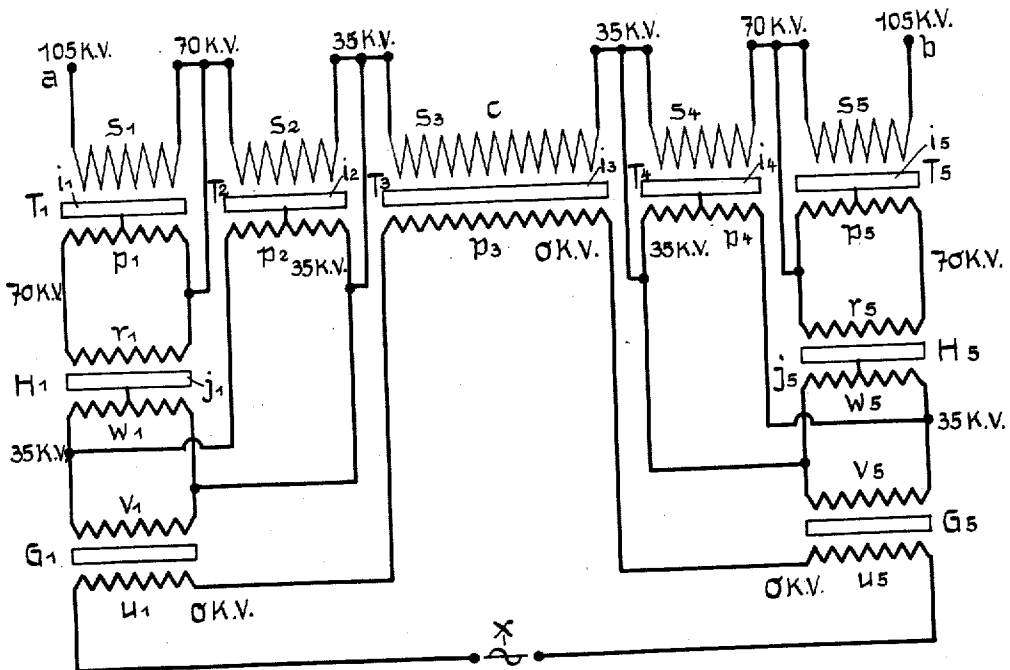


Fig. 6.

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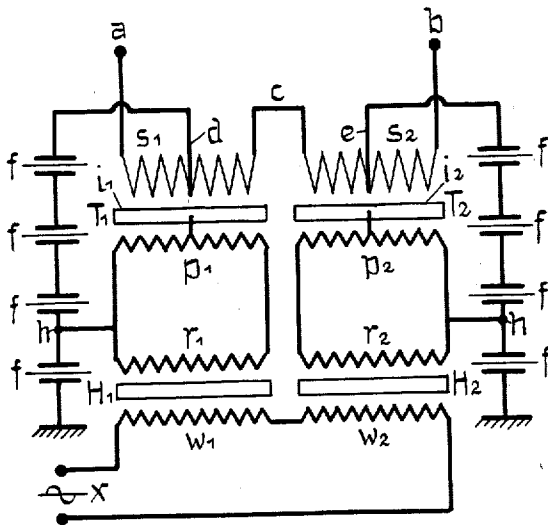


Fig. 7.

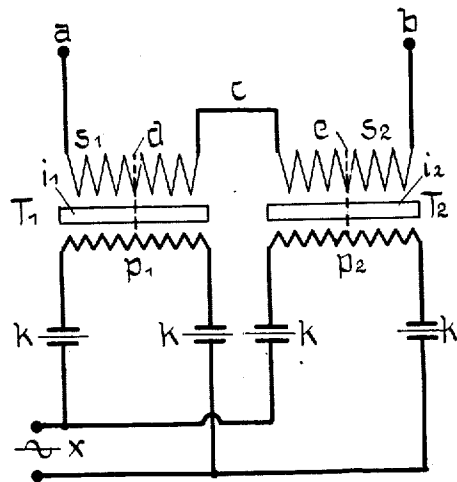


Fig. 8.

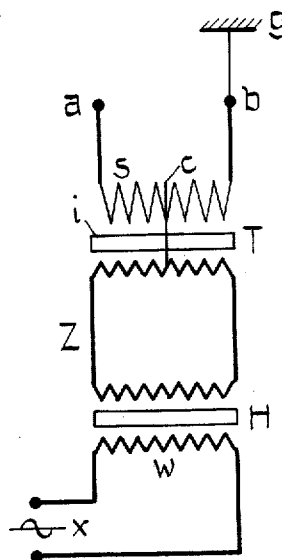


Fig. 9.

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UNITED STATES PATENT OFFICE.

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ELECTRICAL TRANSFORMER SYSTEM.

1,372,653.

Specification of Letters Patent.

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To all whom it may concern:

Be it known that I, FRIEDRICH DESSAUER, a subject of the German Emperor, residing at Frankfort-on-the-Main, in the German Empire, have invented a new and useful Electrical Transformer System, of which the following is a specification.

My invention relates to an electrical high tension transformer system, and has for its object to provide an improved arrangement, as regards compactness, weight, efficiency and working security, for supplying electrical energy at high voltages.

In the accompanying diagrammatical drawings Figures 1, 2 and 3 show some arrangements as heretofore known, while Fig. 4 represents an arrangement according to my invention, and in the Figs. 5, 6, 7, 8 and 9 other embodiments of my invention are illustrated.

In an electrical high tension transformer of a given size, the electrical strain which the insulating layers are subjected to, and thus the danger that those layers be damaged or even pierced, depends upon the potential difference to which the insulating layers are subjected. In the transformers known heretofore, it is, as a rule, impossible to diminish this potential difference under a certain limit—*i. e.* under one half of the voltage, as measured at the ends of the secondary (high tension) winding; even this limit holds good only if the middle point of the secondary coil is maintained on the earth potential. In case, however, the secondary of the transformer is grounded at one of its ends, the potential difference cannot by any means be made smaller than the secondary voltage.

A few examples will make this clear. In Fig. 1^a, I have plotted as abscissæ the number of turns of the secondary winding s of the high tension transformer T (Fig. 1), beginning from the middle m of the secondary, and as ordinates the potential difference, as measured between any point of the secondary and the earth. Then, if in one case the middle m and in the other case one end (b) of the secondary is grounded, the straight lines $a b_1$ and $a b_2$ respectively, show with sufficient approximation the tension which exists between any two points of the secondary winding s , a and b being the ends of the secondary. At a secondary tension of, say, 100 kilovolts, we have, as is to be seen from the diagram, in the first case

($a b_1$) a potential difference of 50 kilovolts between the earth or (what means practically the same) the primary winding w and iron core i on one hand and both a and b on the other hand, in the second case ($a b_2$) a potential difference of 100 kilovolts between the earth or primary w and iron core i on one hand and one end (a) of the secondary on the other hand.

The same takes place in Fig. 2, in which two transformers T_1 and T_2 , connected in series, are used instead of a single transformer. If in this case the conductor c by which the two secondaries s_1 and s_2 are joined together, is connected to the ground, then—supposing the secondary tension between a and b to be 100 kilovolts—the difference of potential between a as well as b on one hand and the primary w_1 (w_2) and iron core i_1 (i_2) on the other hand will again amount to 50 kilovolts (see Fig. 2^a). In any other sort of connection the result is still more unfavorable; the worst result is obtained by grounding one end of the secondary, say b , in which case the full voltage of 100000 is established between the point a and the primary w_1 and iron core i_1 .

Obviously, no other result than in Fig. 1 is arrived at by a double transformation, as in Fig. 3,—*i. e.* by inserting the primary winding p of the high tension transformer T in the circuit of the secondary r of a 1:1 transformer H . If instead of H a step-up transformer would be used, the iron core i of T —its potential being practically that of the earth—would possess a difference of potential against the primary p as well as against the secondary winding s of T . In any case however,—whatever the potential of the iron core i may be—not less than one half of the secondary voltage is present between i as well as w_1 and at least one of the ends of the secondary winding s of T .

With the means, as heretofore known, we are, as is pointed out in the foregoing, bound to deal with a minimum difference of potential (amounting to half the secondary voltage) between those parts of the transforming arrangement which are most exposed to the danger of being damaged. In consequence, the insulating parts of the arrangement must be constructed according to that difference of potential. This drawback is so much the more serious, as the insulating parts in transformers are strained to the utmost by the high voltages which

are in use at present in certain applications of transformers, such as in high voltage testing apparatus or in Roentgen-ray apparatus for the treatment of diseases. Moreover it is to be expected that still higher amounts of voltage will become desirable to be used in those just mentioned applications as well as in high tension work in general. A voltage of more than 100000 requires cumbersome and expensive transformers to fulfil the necessary working conditions.

The essential progress brought about by my invention is involved in the fact that the unvariable relation between the secondary voltage and the strain of the dielectric in transformers exists no longer. The maximum of potential difference between the secondary and other parts of a transformer is no longer limited to at least the half of the secondary voltage; it may be diminished at will. Correspondingly the difference of potential between the secondary and any part of the transformer is diminished.

For the sake of more briefly expressing myself, I shall, in the following, denote as a primary winding that one of two cooperating high tension transformer windings which shows the smaller voltage at its ends, whatever the direction of energy transmission in the high tension transformer (step up or step down transformation) may be. Then according to my invention, the primary coil or coils of one or more high tension transformers of the system are linked to the external (outside the high tension transformer) portion of the path of energy transmission by means of devices which permit the transmission of alternating current energy without the aid of a conductive relation between their energy transmitting parts, such as by transformers or condensers. In this way I obtain the possibility of controlling at will the potential of that portion of the path of energy transmission to which the energy is transmitted by the said devices.

Furthermore, I maintain the primary coil, iron core and other conducting parts of each of the respective transformers at a potential which is the mean of the potential in the respective conductor, less different from the potential of the adjacent turns of the secondary coil than this latter potential differs from the potential of the ground.

I will now describe in detail, by way of example, a number of embodiments of my invention.

Fig. 4 shows two transformers T_1 and T_2 the secondary coils s_1 and s_2 of which are connected in series, the ratio of transformation in each transformer being that which the system as a whole is intended to possess. The primary windings p_1 and p_2 of T_1 and T_2 form part each of the secondary circuit

of another transformer H_1 and H_2 respectively. The ratio of transformation of H_1 and H_2 need not necessarily differ from 1:1; H_1 and H_2 are only to separate the primaries of the high tension transformers T_1 and T_2 from each other and from the source of current x . The point of junction c of the secondaries s_1 and s_2 of T_1 and T_2 is grounded; therefore, at a secondary voltage of 100000 between the terminals a and b , as in the case illustrated in the diagram Fig. 4^a, the potential difference between either a or b on one hand and the earth on the other hand is reduced to 50 kilovolts. In consequence 25 kilovolts are established between the ground and the middle d (and e) of any of the two secondary windings s_1 and s_2 ; the points d and e are connected to the primary winding p_1 and p_2 as well as to the iron cores i_1 and i_2 of T_1 and T_2 respectively. Thence, the difference of potential between the end a of the secondary coil and the primary winding and iron core of T_1 —i. e. the maximum potential difference occurring in T_1 —is $50-25=25$ kilovolts. Thus the maximum of the difference of potential between any two adjacent groups of conductors in the system is limited to one quarter of the secondary voltage; correspondingly, the electrical strain is a quarter of what it otherwise would amount to. The transformers H_1 and H_2 are, it is true, also bound to sustain 25 kilovolts between their primary and secondary windings, but this requirement is easy to be fulfilled, both windings possessing equal and small numbers of turns.

As the secondary windings s_1 and s_2 are connected in series, it is obvious that a single secondary winding may be used instead of s_1 and s_2 . Therefore, the essential feature of my system, as shown in Fig. 4 (as well as those of Figs. 5, 6, 7 and 8), is constituted by the fact that at least three high tension transformer windings—the single secondary winding, as just pointed out, and the primary windings p_1 and p_2 —are used, and that at least two of them— p_1 and p_2 —are placed each in a branch— H_1 , T_2 and H_2 , T_1 respectively—of the path of energy transmission, every branch including (in addition to the high tension transformers) one or more of the devices which permit of the transmission of energy without conductive relation— H_1 and H_2 respectively.

Both for the fact that my transformer system is somewhat less simple than the heretofore known single high tension transformers (as in Fig. 1) and the loss of energy in the transformers H_1 and H_2 , are far more than compensated for by the advantages of my invention: As the voltage acting upon the insulation of the high tension transformers is reduced to one half, the price of the high tension transformers is

reduced to much less than a half, the costs of the transformers H_1 and H_2 being therefore more than balanced; and this will be the more appreciable, the higher the voltages are which are to be dealt with. Moreover, the working security is greatly increased in my system, and I wholly avoid any loss of energy by the phenomenon of silent or glow discharge (sputtering), well known in high tension work, which loss otherwise attains considerable amounts.

Fig. 5 illustrates another form of my system, comprising three high tension transformers T_1 , T_2 and T_3 having their secondaries connected in series, and only two further transformers H_1 and H_2 . The levels of potential of the groups of conductors—supposing the middle c of the secondary winding s_2 to be grounded and 140 kilovolts to be produced between the points a and b —are indicated in the diagram Fig. 5^a as well as in Fig. 5.

In some cases, especially with a very high voltage, I make use of more than a double transmission (as in Figs. 4 and 5), for instance of a three-fold transformation, as illustrated in Fig. 6, thereby dividing the difference of potential between the high tension circuit and the source of current (or translating apparatus) into three or more steps. In this case, by branching the path of energy transmission in some of the further transformers, as in Fig. 6 (transformers G_1 and G_2), I preferably arrange these transformers so as to supply energy to more than one transformer, for instance to two other transformers (H_1 , T_2 and T_4 , H_2 respectively), in this way reducing the number of transformers required. Supposing the middle c of the secondary winding s_3 to be grounded and 210 kilovolts to be present between the points a and b , I have in Fig. 6 again indicated the potentials of the diverse groups of conductors.

Obviously, any one of the arrangements of Figs. 4, 5 and 6 can easily be formed out of its precedents (e. g. Fig. 6 out of Fig. 5, 4 or 1), merely by adding transformers. This is an important advantage of my system—viz., I am enabled, by my system, to adapt, by the mere addition of transformers, a given alternating current supply apparatus to a higher range of voltage, and nevertheless to make use of all the parts of the given apparatus as before. Preferably, I avail myself of standardized types of additional transformers (especially in the form of 1:1 transformers), their manufacture and repair being greatly simplified.

As is demonstrated by Fig. 7, I may modify my system, so as to allow the potential of any of the several groups of conductors to be regulated at will. In Fig. 7, the middle d (e) of the secondary winding s_1 (s_2) of every one of the two high ten-

sion transformers T_1 and T_2 is connected to the ground by a series of condensers f , and another connection is made between the circuit of the respective primary winding p_1 (p_2) and a point h in the set of condensers. According as I choose that point of connection h , I obtain, within the limits of the potential of the middle of the secondary winding on one hand, and the ground on the other hand, any desired amount of potential in the primary winding p_1 (p_2) and iron core i_1 (i_2). Instead of a battery of condensers, as in Fig. 7, I may make use of an adjustable resistance to bring about the adjustment of potential. In some cases I find it advisable to impart from a separate source of electrical energy the desired amount of potential to the diverse groups of conductors, instead of deriving their electrical charge from the high tension transformer or transformers.

As already mentioned, not only transformers but any device capable of transmitting electrical energy without a conductive relation between its energy transmitting parts, as, for instance, condensers, may be used to produce the separation of the groups of conductors and therefore to enable their level of potential of being adjusted. This form of my system is exemplified by Fig. 8. Fig. 8 is in accordance with Fig. 4 except that the place of the transformers H_1 and H_2 of Fig. 4 is taken by condensers k .

The artificial adjustment of the potential of the groups of conductors, according to my invention, may be advantageously applied even to such cases in which the maximum difference of potential between the secondary winding and the other parts of one and the same transformer needs not be reduced to less than one half of the secondary voltage. In the case, say, of a high tension transformer with one end of its secondary winding grounded by any reason, the maximum difference of potential acting upon the insulating layers in the arrangement, as known heretofore, amounts—as is stated above—to the total of secondary voltage of the transformer, and cannot be reduced by any means. By inserting an intermediate circuit, the level of potential of which is made adjustable, according to my invention, I reduce the strain of the insulating layers to one half of what is unavoidably amounted to—*cet. par.*—in the heretofore known transformers with one end of the secondary winding grounded. This is demonstrated by Fig. 9 which shows an arrangement similar to that of Fig. 3. As already stated in connection with Fig. 3, it is impossible to reduce the strain of the insulating layers by a mere repeated transformation. If, however, the intermediate circuit Z and iron core i is, as in Fig. 9, connected to the middle c of the secondary (high ten-

sion) winding s , or otherwise kept on a level of potential situated between the potentials of the ends a and b of s on one hand and of the supply circuit w on the other hand, then the strain can be reduced to a half, even if one end (b) of the secondary winding s is in connection with the ground g .

In many cases, I have found, that the connection between the iron cores and windings, as shown in Figs. 4-9, may as well be omitted, as the iron cores, being embedded between the coils, usually adopt automatically an average level of potential as compared with the surrounding coils.

What I claim is:

1. In a high tension transformer system, a high tension transformer, devices for linking the primary coil thereof with the source of alternating current, said devices having alternating energy transmitting parts in nonconductive relation, and means for maintaining a less difference of potential between the iron core and primary coils, on the one hand, and the adjacent turns of the secondary, on the other, than that existing between the latter and ground.

2. A high tension system comprising one or more high tension transformers, one or more transformers linking the primary coils of said high tension transformers with a source of alternating current, said high tension transformers having conductive couplings between each primary coil, core, and coil of high tension circuit thereof at a point in said circuit between which and the ground the maximum difference of potential is equal to or greater than the maximum potential difference between any turn of said high tension circuit and the primary coil coupled therewith.

3. A high tension system comprising one or more high tension transformers, one or more transformers having an approximate one to one ratio of transformation for linking the primary coils of said high tension transformers with a source of alternating current, said high tension transformers having conductive couplings between each primary coil, core, and coils of high tension circuit thereof at a point in said circuit between which and the ground the maximum difference of potential is equal to or greater than the maximum potential difference between any turn of said high tension circuit and the primary coil coupled therewith.

4. A high tension system comprising one or more high tension transformers, one or more transformers linking the primary coils of said high tension transformers with a source of alternating current, said high tension transformers having couplings between such primary coil, core, and coils of high tension circuit thereof at a point in said circuit between which and the ground the maximum difference of potential is equal

to or greater than the maximum potential difference between any turn of said high tension circuit and the primary coil coupled therewith.

5. In a high tension transformer system, three or more high tension transformer windings, two or more branches of energy transmission, each branch including one of said windings and one or more transformers, the primary coils of the transformers being coupled with a point of the high tension circuit between which and the turns of the secondary coil adjacent to the corresponding primary there is a difference of potential equal to or less than the maximum potential difference between said secondary coil and the ground.

6. In a high tension transformer system, three or more high tension transformer windings, two or more branches of energy transmission, each branch including one of said windings and one or more transformers, the primary coils of the transformers being coupled with a point of the high tension circuit between which and the turns of the secondary coil adjacent to the corresponding primary there is a difference of potential equal to or less than the maximum potential difference between said secondary coil and the ground, the said intermediate transformers having an approximate one to one ratio of transformation.

7. In a high tension transformer system, a high tension transformer, devices for linking the primary coil thereof with alternating current energy, said devices having alternating energy transmitting parts in nonconductive relation, and means for maintaining a less difference of potential between conductive parts of the transformer adjacent to each other than that existing between high tension turns thereof and the ground.

8. In a high tension transformer system, one or more high tension transformers, a plurality of transformers linking the primary coils of said high tension transformers with the external portion of the path of energy transmission, said primary coils and iron cores of the respective transformers having conductive couplings between each primary coil and coil of high tension circuit thereof at a point in said circuit between which and the ground the maximum difference of potential is equal to or greater than the maximum potential difference between any turn of said high tension circuit and the primary coil coupled therewith, three or more steps of potential thereby being formed in the system, and the path of energy transmission being branched on one or more of the intermediate levels of potential produced by said steps of potential.

9. In a high tension transformer system, one or more high tension transformers, a

plurality of transformers having an approximate one to one ratio of transformation for linking the primary coils of said high tension transformers with the external

5 portion of the path of energy transmission, said primary coils and iron cores of the respective transformers having conductive couplings between each primary coil and
10 coil of high tension circuit thereof at a point in said circuit between which and the ground the maximum difference of potential is equal to or greater than the maximum
15 potential difference between any turn of said high tension circuit and the primary coil coupled therewith, three or more steps of potential thereby being formed in the system, and the path of energy transmission being branched on one or more of the intermediate levels of potential produced by said
20 steps of potential.

10. A high tension system comprising a plurality of primary and secondary transformer windings having the secondary windings of high potential circuits connected in series, a source of alternating
25 electrical energy, and means for supplying the primary transformer windings with energy derived from said source and insulating said source therefrom whereby a potential difference may be maintained between
30 said primary windings different from the potential of the source.

11. A high tension system comprising a plurality of primary and secondary transformer windings having the secondary windings of high potential circuits connected in series, a source of alternating electrical energy, and means comprising
35 separate transformers of preferably a one to one ratio of transformation as compared with the ratio of the high tension transformer windings for supplying the primary transformer windings with energy and in-
40

45 sulating said source therefrom whereby a potential difference may be maintained between said primary windings different from the potential of the source.

12. A high tension system comprising a plurality of primary and secondary transformer windings having the secondary windings of high potential circuits connected in series, a source of alternating electrical energy, means for supplying the primary transformer windings with energy derived from
50 said source, and couplings between the said primary windings and their corresponding secondary high tension windings at suitable points in the high tension circuit.

13. A high tension system comprising a plurality of primary and secondary transformer windings having the secondary windings of high potential circuits connected in series, a source of alternating electrical energy, means for supplying the primary transformer windings with energy derived
60 from said source, and means for keeping said primary windings at a desired potential with respect to said high tension windings.

14. In a high tension system, a transformer having its primary and secondary
70 conductively coupled at a point between which and the ground the maximum difference of potential is equal to or greater than the maximum potential difference between any turn of the high tension circuit and the primary coupled therewith, a source of alternating current for supplying said primary winding with energy, and means
75 for keeping said transformer insulated from said source.

DR. FRIEDRICH DESSAUER.

Witnesses:

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GUSTAV SPIER.