Dec. 13, 1955 R. W. ANNIS 2,727,205

VARIABLE VOLTAGE TRANSFORMERS

Filed Feb. 5, 1953

Fig. 1

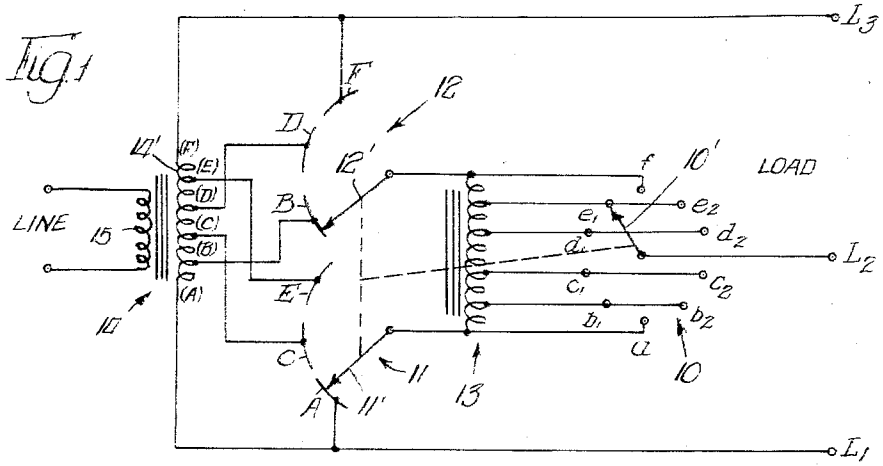


Fig. 2

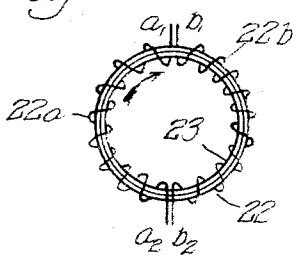


Fig. 4

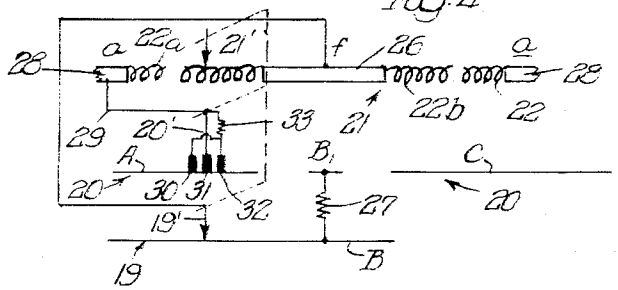
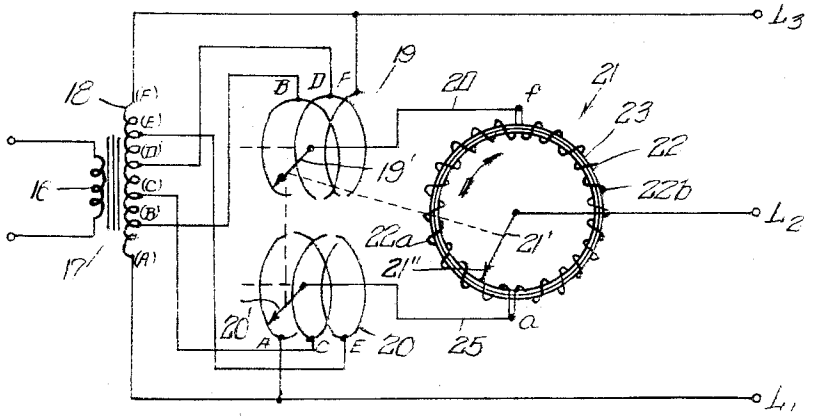


Fig. 3



INVENTOR.
Robert W Annis,
BY
Cromwell, Greist & Warden
Attys.

United States Patent Office 2,727,205 Patented Dec. 13, 1955

2,727,205

VARIABLE VOLTAGE TRANSFORMERS

Robert W. Annis, Champaign, Ill.

Application February 5, 1953, Serial No. 335,229

10 Claims. (Cl. 323—43.5)

The present invention relates to improvements in a variable alternating current potential source or potential converter by which a very flexible control of voltage, for example a supply for a motor operating system, is made possible. The principles of the invention are not limited in application to any particular installation or setting, however.

In one embodiment the improvement takes the form of an arrangement of transformer and multiple switch means adapted for step-by-step adjustment, which arrangement improves substantially the smoothness and versatility of operation of related conventional switching transformers in producing fine voltage changes over a wide range, without corresponding increase in cost and without the complexity of operation characteristic of such known transformer arrangements. In other embodiments the improvement involves the use of an improved, continuously variable transformer and improved switching means associated therewith to eliminate the elaborate switching operations required in the operation of known variable transformers of extended range, enabling unidirectional operation of a control member to produce a given kind and degree of voltage change smoothly over a given wide range.

In short, it is a general object of the invention to provide, in one embodiment or another, a relatively simple variable voltage transformer and switching unit adapted to effect extremely fine voltage regulation over a wide range, and to do this more easily and smoothly than has heretofore been possible.

Another general object is to provide a unit which minimizes the number of necessary contacts, taps and other switching or similar connections and also minimizes or eliminates the necessity for complex switching operation, with repeated reversals of the direction of manipulation of a selector or control member, in order to traverse a full range of voltage selection, or even a sub-range thereof.

More specifically, it is an object of the invention to provide a voltage control unit featuring a relatively simple, slidably adjustable switching device, constituted in one illustrative embodiment by contact arms, preferably mechanically coupled, which are selectively engaged with spaced taps of a transformer secondary, together with a multiple contact manual selector switch whose contacts are tapped at spaced points to a coil arranged in circuit with those arms; and in another embodiment by similar coupled contact arms engaging certain transformer-supplied conducting helices, and continuously adjustable thereon without circuit interruption, together with an improved auto-transformer type output device.

A still further object is to provide a unit of the sort described in the preceding paragraph in which the transformer device is characterized by a reversely wound toroidal coil slidably and unidirectionally engaged by a manually adjustable contact arm, thereby attaining the entire range, upward or downward, of voltage selection

of the device without manual reversal of movement of the contact arm.

Yet another object is to provide such a reversely wound variable transformer device.

A still further specific object is to provide a continuously variable voltage transformer installation as described above, featuring a rotatively sliding, transformer coil contacting arm, which may be coupled mechanically with the contacting arm or arms of a switching device, preferably continuous or non-interruptive in action, to produce extremely fine voltage variations in sub-ranges very flexibly and smoothly determined by the setting of the switching device.

The foregoing statements indicate the general nature of the invention; other and more specific objects will be apparent upon a full understanding of the construction and operation of the improved variable voltage means. Several embodiments are presented for the purpose of illustration. However, the invention can be incorporated in still other modified forms coming equally within the scope of the appended claims.

In the drawings:

Fig. 1 is a schematic diagram showing the invention as embodied in a step-by-step switching, variable transformer voltage control unit;

Fig. 2 is a schematic diagram of an improved, reversely wound toroid type transformer adapted, in accordance with another and preferred embodiment, to enable continuous unidirectional voltage control operation;

Fig. 3 is a schematic diagram of a wide range voltage control featuring the transformer arrangement of Fig. 2; and

Fig. 4 is a schematic showing of a further refinement on the continuously variable voltage transformer system of Fig. 3.

A first embodiment of the invention, shown in Fig. 1, provides a voltage control of wide range and fine selectivity or versatility. It embodies a manually controlled transformer of the general type illustrated and described in the patent to Karplus et al. 2,009,013 of July 23, 1935. The system shown in Fig. 1 comprises three switches **10, 11, 12** having contact arms **10'**, **11'** and **12'** respectively, which are mechanically coupled and driven together. Switch **10** has contacts *a*, b_1 and b_2, c_1 and c_2, d_1 and d_2, e_1 and e_2, and *f* arranged in circumferential order as shown, which contacts are adapted to be selectively engaged by the contact arm **10'** of switch **10**. That contact arm is electrically connected with the center terminal L_2 of the three-wire line which may lead to an alternating current load (not shown).

Contacts *a* and *f* are connected to the ends of the coil of a transformer **13** of the type described in the Karplus et al. patent, while the remaining contacts are connected to intermediate taps on the coil. The contact arms **11'**, **12'** of the switches **11, 12**, which arms are operated as a gang, are also electrically connected to the terminals of the coil of transformer **13**.

A second transformer **14** has its coil **14'** arranged as a secondary associated with a primary winding **15**, the primary being supplied from a standard alternating current source. Coil **14'** is connected at its ends to the remaining two load terminals L_1 and L_3. Intermediate taps thereof are connected to contacts of the switches **11, 12**. As shown switch **11** has fixed contacts A, C, E and switch **12** has similar contacts B, D, F. The extreme contacts A and F are connected to the terminals L_1 and L_3 while intermediate contacts C and E and B and D are connected to the intermediate taps of secondary coil **14'**, the taps being designated by corresponding reference characters.

The operation of the unit just described is as follows:

Commencing with load terminal L_2 at the same potential as terminal L_1, arm **10'** will engage contact *a* of switch **10**, arm **11'** will engage contact A and arm **12'** will be open circuited. In order to alter the potential of terminal L_2 in the direction of the terminal L_3, contact arm **10'** is moved clockwise to contact b_1, contact arm **11'** remaining in engagement with contact A and arm **12'** will engage contact B. To further raise the potential of terminal L_2, arm **10'** is progressively engaged with contacts c_1, d_1 and e_1, while arms **11'**, **12'** retain engagement with contacts A and B, respectively. When arm **10'** reaches contact *f*, arm **11'** open circuits. Arm **12'** remains in engagement with contact B.

Continuing with the adjustment, arm **10'** is next moved to engagement with contact e_2, contact arm **11'** engages contact C and arm **12'** remains in engagement with contact B. This procedure is repeated until the potential of terminal L_2 is raised to that of L_3. Each time that contact arm **10'** engages contact *a*, arm **12'** is open circuited and each time arm **10'** engages contact *f*, arm **11'** is open circuited. Thus it is possible to step the potential of intermediate terminal L_2 from that of terminal L_1 to that of terminal L_3 by the values of the steps of transformer **13**. Switches **10**, **11** and **12** may be mechanically coupled by gears, non-linear linkages or the like, depending upon the particular design. More units can be cascaded to reduce the number of taps, but this increases the number of switch sections. Transformer **14** is shown as an isolation transformer but may also be an auto transformer. As an alternative arrangement, the switching may be done by relays to give the above sequence.

The system has the advantage that the cost of transformer **14** may be reduced by reducing the number of taps thereof, the savings being employed for a smaller transformer **13** having additional taps and added switching. The rating of transformer **13** has the same current value as transformer **14**, but its voltage is divided by the number of secondary terminals, N, minus one. Thus the kv.-a. rating of transformer **13** is the kv.-a. rating of transformer **14** divided by the value N minus one.

If the voltage steps of transformer **13** are small enough a still smoother switching variation may be obtained by the use of a high resistance brush sliding between the contacts of switch **10**, engaging and short circuiting two of the contacts of the latter in intermediate position, as described in the Karplus et al. patent identified above.

In a motor speed control application of the circuit of Fig. 1, the primary connections of the transformer may be open delta, or by adding a tertiary winding and auxiliary transformer delta delta X or Y delta X. Primary and tertiary windings of this sort are well known to the art.

The voltage adjusting system illustrated in Fig. 1 has the important advantage of ease and simplicity of manipulation. Adjustment of the contactor arm **10'** is unidirectional, i. e., clockwise for an increase in voltage output and counterclockwise for a decrease. The complexity of operation introduced by the need to reverse the direction of movement of a contactor when transposing from a given sub-range to a preceding or succeeding sub-range is eliminated.

A modified and improved adaptation of the invention is illustrated in Fig. 3 of the drawings, a component thereof, in the form of an improved transformer device or unit, being shown in Fig. 2. This has the same important advantage of unidirectional contactor manipulation. Moreover, it embodies a toroidal coil transformer in association with a rotatively adjustable coil contacting arm to obtain continuous uninterrupted voltage change operation from the transformer. The coil winding is of an improved nature, as will be described.

In this embodiment, reference being had to Fig. 3, line voltage leads are connected to the primary **16** of a transformer **17**, the secondary **18** of which is provided with a plurality of taps, as in the form of Fig. 1. These taps are connected by leads with two sectional helices, designated **19** and **20** and hereinafter described in greater detail; and the helices are in turn connected to an improved rotatively adjustable transformer, generally designated by the reference numeral **21**. The transformer, per se, is illustrated in Fig. 2.

It is readily seen that the system of Fig. 3 involves the same combination or relationship of components shown in Fig. 1, with the substitution of helices **19**, **20** for the rotatively adjustable switches **12**, **11**, respectively, and the rotatively adjustable toroidal transformer **21** for the combined transformer **13** and rotative switch **10**. This continuous type of construction is much simpler to make than the switch type device of Fig. 1.

Contact arms **19'**, **20'** and **21'** of the respective helical control devices **19**, **20** and **21** are mechanically coupled for rotation together, as illustrated in Fig. 3. Control devices or helical switches **19**, **20** are separated into arcuate sections of a trifle less than aliquot parts of 360° each, which are progressively engaged slidably by arms **19'**, **20'** as the latter rotate in timed relation with arm **21'**. Thus, device **20** comprises a first segment A of 180° arc contacted by arm **20'**, this segment being tapped to the terminal of transformer secondary **18**. The first arcuate segment B of device **19** is a trifle less than 360° in extent, as each of the segments herein mentioned are a trifle less than the stated arc, so as to provide an open circuit portion in the switching cycle. Segment B effects and continues a connection of its arm **19'** to the secondary at B through this one-half rotation of arm **20'**, for a circuit through secondary coil portion A—B, plus the further 180° arc, during which arm **20'** of device **20** switches over to a second 360° arcuate segment C. When arm **20'** is half way around segment C, arm **19'** switches to a second 360° segment D of device **19**, thus making corresponding electrical connections at C—D of secondary **18**. Continued rotation of arms **19'**, **20'** alters the circuit connections at transformer **17**, as will be understood, and, the final increment of rotation finds contactor **19'** of device **18'** at the end of a terminal 180° segment F of the latter, completing its portion of a circuit to end tap F of the transformer secondary, with contactor **20'** at the end of the final 360° segment E of device **20**.

It is evident from the foregoing, that a complete cycle of rotative manipulation of the voltage changing system of Fig. 3 involves successive reversals of polarity of current due to successive, though relatively uninterrupted switching at secondary **18**. Accordingly, in order to retain desired unidirectionality of manipulation for a voltage change in a given direction, it is necessary that toroidal winding **22** of transformer **21** be continuous about its annular core **23**, and also be capable of bringing about compensating changes at each 180° of rotation of arm **21'** to offset the changes of polarity referred to. The considerably improved simplicity of the Karplus type variable transformer, as compared with the relatively complicated switch transformer unit **10**, **13** of Fig. 1, is more or less obvious and dictates the choice of the former, provided it can be adapted to the peculiarity of operation of devices **19**, **20**.

This is done by reversing the direction of winding of the two halves of the continuous transformer coil **22**, thus providing reverse polarity of the two. The thus wound coil components, designated **22***a* and **22***b*, must be identical in wire size and number of turns. The former is clockwise and the latter counterclockwise as the coil progresses around core **23** in the direction of the arrow in Fig. 2. If an alternating current voltage V is applied to coil terminals a_1, a_2 (Fig. 2) and if terminal a_1 is also connected to terminal b_1, the voltage measured between terminals a_2 and b_2 would be zero; but if the windings **22A**, **22B** were in the same direction the voltage between a_2 and b_2 would be 2 v.

Now if arm **21'** is equipped with a resistance brush

21'' (Fig. 3), as in the Karplus patent, when arm **21'** is rotated in the direction of the arrow from coil tap *a* to tap *f*, output voltage at terminals L_1, L_2 will change from zero to the voltage applied across the taps, and by completing the revolution from tap *f* to tap *a* the output voltage will normally again reduce to zero.

Connecting input leads between contact arms **19'**, **20'** and the taps *f*, *a*, respectively, and output leads with the helix termini E, F and with the contact arm **21'**, as illustrated in Fig. 3, results in the desired compensation to offset changes in polarity produced by switching action as described above.

Aside from the advantage of unidirectional rotative manipulation to select desired increases or decreases in voltage, the reversely wound auto-transformer **21** may be designed for fixed current and voltage ratings, and the range of output voltage then governed by the rating of a selected transformer **17** and the number of arcuate segments in the switch devices **19**, **20**. The latter are comparatively easy to build in assorted sizes and capacities, permitting standardization of design of the auto-transformer in a few different ratings to meet the requirements of a number of installations.

A refinement of the continuous switching circuit or system of Fig. 3 is illustrated in Fig. 4 of the drawings. In this figure, the various switching devices and coils, although intended to be circular or helical and toroidal in shape as in Fig. 3, are depicted for the sake of simplicity and clarity in rectilinear outline. However it is to be understood that in these respects, as well as in regard to reverse winding of the halves of toroidal coil **22**, the two arrangements are identical. The system of Fig. 4 merely introduces improvements to reduce the magnitude of the switching transients, i. e. to keep from short circuiting between any two live voltage taps and not to allow the external path between taps or terminals *a*, *f* to be open circuited during switching. For further simplification, the description to follow will refer to the switching of contact arm **20'** of switch **20** from 180° helical switch segment A over onto 360° segment C; however it is to be understood that similar provisions are made and the same description will apply to the transition of contact arm **19'** from segment to segment of helical switch device **19**.

In accordance with the improvement, a contact surface **26** is provided for tap or terminal *f* which is of sufficient circumferential length to allow a conditioning segment B_1 to be inserted between helical segments A and C, in predetermined circumferential spacing thereto as determined by the width of the brush structure, to be described, of the contact arm **20'**. The relatively short segment B_1 is connected through a resistor **27** with the helical segment B of device **19**. A similarly elongated contact surface **28** will of course be provided at the opposite tap or terminal *a*.

The brush of the rotatively sliding contact arm **20'** is connected by a lead **29** with this contact surface **28**, the brush comprising three contacts **30**, **31**, **32**. Contact members **30** and **32** are connected to one another but are insulated from the intermediate member **31**, which actually serves as the original single contact brush of arm **20'**, being directly connected to lead **29**. A resistor **33** connects the coupled contact members **30**, **32** with that lead.

For the circuit contemplated by the present improvement, resistor **33** should be of about one-half to one-third the value of resistor **27**. The latter should have a value which will draw a current equal to the excitation current of the transformer **13** of Fig. 1 or of transformer **21** of Fig. 3 at rated voltage, as a highest resistance value. This current is to be approximately 5% of the rated transformer excitation current at rated transformer voltage, as a lower resistance value.

Now considering that the contact arms **19'**, **20'** and **21'** are turned in a direction to move brush **20'** along helical segment A of switch device **21** toward the succeeding segment C, the following events occur in sequence. Brush contact member **32** disengages from segment A as transformer brush arm **21''** contacts the surface **26** of terminal *f* and remains in contact with that surface. Next, the brush contact member **31** disengages from segment A, which inserts resistor **33** in series with the transformer coil **22**. This is followed by the engagement of brush contact **32** with the short helical bridge segment B_1, causing resistor **27** to be connected in parallel with the transformer coil.

Brush contact member **30** is now disengaged from segment A and continued motion carries the members **32** and **31** across bridging segment B_1. This segment is long enough to short member **32** to **31** or **31** to **30** as they are switched as described. When brush member **30** has been engaged with segment B_1 the member **32** remote therefrom engages the 360° segment C. This is followed by disengagement of brush member **30** from bridging segment B_1, then engagement of member **31** with segment C. After this takes place the transformer contact arm **21'** leaves contact surface **26** of terminal *f* and continues along the portion **22***b* of transformer coil **22**.

There are other possible combinations of resistance and switching arrangement which will work satisfactorily, but the arrangement which is described presents very desirable smoothness of control, preventing shorting of voltage taps as well as opening of the circuit between terminals *a* and *f* during the switching procedure. It of course also affords all of the advantages of continuity and unidirectionality of voltage selection referred to in connection with the preceding embodiments.

I claim:

1. In a variable voltage system, the combination of a first selector unit comprising an elongated impedance member, and means including at least one adjustable contactor to make electrical contact with said impedance member at a point between the ends thereof and at points on either side of said first point, a second selector unit having an elongated impedance member and a rotative contactor electrically engageable therewith, said rotative contactor having electrical contact with said second impedance member in a range of substantially more than 180° rotation of said contactor, there being points on said second impedance member which are electrically engaged at substantially the same electrical level, respectively, by said rotative contactor in one 180° segment of its rotation and in another succeeding segment of its rotation, and means electrically connecting said selector units whereby manipulation of said adjustable contactor of said first unit successively reverses electrical polarity at said first impedance member and whereby unidirectional rotation of said rotative contactor from one of said segments into the other effects unidirectional alteration of a voltage flowing in said second impedance and rotative contactor.

2. In a variable voltage system, the combination of a first selector unit comprising an elongated impedance member, and means including at least one adjustable contactor to make electrical contact with said impedance member at a point between the ends thereof and at points on either side of said first point, a second selector unit having an elongated impedance member and a rotative contactor electrically engageable therewith, said rotative contactor having electrical contact with said second impedance member in a range of substantially 360° rotation of said contactor, there being points on said second impedance member which are electrically engaged at substantially the same electrical level, respectively, by said rotative contactor in one 180° segment of its rotation and in the other segment of its rotation, and means electrically connecting said selector units whereby manipulation of said adjustable contactor of said first unit successively reverses electrical polarity at said first impedance member and whereby unidirectional rotation of said rotative contactor from one of said segments into the other effects

unidirectional alteration of a voltage flowing in said second impedance and rotative contactor.

3. A variable voltage system in accordance with claim 2, in which said segments of said second impedance comprise connected transformer coil portions wound in opposite directions.

4. A variable voltage system in accordance with claim 2, in which said second impedance comprises a continuous transformer coil and in which portions of said coil are wound in opposite directions from the junction point of said segments of rotation of said rotative contactor.

5. In a variable voltage system, the combination of a first selector unit comprising an elongated impedance member, a pair of contactors positionable in electrically conductive relation to said member, and means so connecting said respective contactors with said impedance member as to make successive electrical contact with the latter at points in staggered alternation along the length thereof, a second selector unit comprising an elongated impedance member and a rotative contactor electrically engageable therewith, said rotative contactor having electrical contact with said second impedance member in a range of substantially more than 180° rotation of said contactor, there being points on said second impedance member which are electrically engaged at substantially the same electrical level, respectively, by said rotative contactor in one 180° segment of its rotation and in another succeeding segment of its rotation, and means electrically connecting said selector units whereby manipulation of said contactors of said first unit successively reverses electrical polarity at said first impedance member and whereby unidirectional rotation of said rotative contactor from one of said segments into the other effects unidirectional alteration of a voltage flowing in said second impedance and rotative contactor.

6. In a variable voltage system, the combination of a first selector unit comprising an elongated impedance member, a pair of contactors positionable in electrically conductive relation to said member, and means so connecting said respective contactors with said impedance member as to make successive electrical contact with the latter at points in staggered alternation along the length thereof, said means including a ganging connection between the contactors, a second selector unit comprising an elongated impedance member and a rotative contactor electrically engageable therewith, said rotative contactor having electrical contact with said second impedance member in a range of substantially more than 180° rotation of said contactor, there being points on said second impedance member which are electrically engaged at substantially the same electrical level, respectively, by said rotative contactor in one 180° segment of its rotation and in another succeeding segment of its rotation, and means electrically connecting said selector units whereby manipulation of said contactors of said first unit successively reverses electrical polarity at said first impedance member and whereby unidirectional rotation of said rotative contactor from one of said segments into the other effects unidirectional alteration of a voltage flowing in said second impedance and rotative contactor.

7. In a variable voltage system, the combination of a first selector unit comprising an elongated impedance member, a pair of contactors positionable in electrically conductive relation to said member, and means so connecting said respective contactors with said impedance member as to make successive electrical contact with the latter at points in staggered alternation along the length thereof, a second selector unit comprising an elongated impedance member and a rotative contactor electrically engageable therewith, said rotative contactor having electrical contact with said second impedance member in a range of substantially 360° rotation of said contactor, there being points on said second impedance member which are electrically engaged at substantially the same electrical level, respectively, by said rotative contactor in a first 180° segment of its rotation and in the second 180° segment of its rotation, and means electrically connecting said selector units whereby manipulation of said contactors of said first unit successively reverses electrical polarity at said first impedance member and whereby unidirectional rotation of said rotative contactor from one of said segments into another effects unidirectional alteration of a voltage flowing in said second impedance and rotative contactor.

8. In a variable voltage system, the combination of a first selector unit comprising an elongated impedance member, a pair of contactors positionable in electrically conductive relation to said member, and means so connecting said respective contactors with said impedance member as to make successive electrical contact with the latter at points in staggered alternation along the length thereof, said means also including a ganging connection between the contactors, a second selector unit comprising an elongated impedance member and a rotative contactor electrically engageable therewith, said rotative contactor having electrical contact with said second impedance member in a range of substantially 360° rotation of said contactor, there being points on said second impedance member which are electrically engaged at substantially the same electrical level, respectively, by said rotative contactor in a first 180° segment of its rotation and in the second 180° segment of its rotation, and means electrically connecting said selector units whereby manipulation of said contactors of said first unit successively reverses electrical polarity at said first impedance member and whereby unidirectional rotation of said rotative contactor from one of said segments into another effects unidirectional alteration of a voltage flowing in said second impedance and rotative contactor.

9. A variable voltage system in accordance with claim 8, in which said segments of said second impedance comprise connected transformer coil portions wound in opposite directions.

10. A variable voltage system in accordance with claim 8, in which said second impedance comprises a continuous transformer coil and in which portions of said coil are wound in opposite directions from the junction point of said segments of rotation of said rotative contactor.

References Cited in the file of this patent

UNITED STATES PATENTS

1,422,653	Berry	July 11, 1922
2,205,476	Hunter	June 25, 1940
2,452,784	Noodleman	Nov. 2, 1948