United States Patent

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[73] Assignee Maschinenfabrik Reinhausen Gebruder Scheubeck K.G.
Regensburg, Germany
[32] Priority Apr. 12, 1969
[33] Germany
[31] P 19 18 606.2

[54] **TAP-CHANGING REGULATING TRANSFORMER WITH SOLID-STATE CIRCUITRY**
10 Claims, 8 Drawing Figs.

[52] U.S. Cl. 323/43.5S, 200/16R
[51] Int. Cl. H01f 29/04
[50] Field of Search .... 200/16 (R), (Inquired); 323/24, 43.5 (R), 43.5 (S); 317/11

[56] References Cited

UNITED STATES PATENTS

3,164,689 1/1965 Pensis 323/43.5X

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672,500 3/1939 Germany 323/43.5

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Assistant Examiner—A. D. Pellinen
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ABSTRACT: A tap-changing regulating transformer is provided with a tapped winding, a selector switch, a triggerable solid-state circuitry for performing tap-changing operations, trigger pulse generators for triggering said circuitry and automatic control circuitry for controlling said trigger pulse generators. The solid-state circuitry carries the load current permanently, i.e. not only during tap-changing operations, thus dispensing with the provision of current-carrying shunting switches across the solid-state circuitry for carrying load currents during steady state periods when no tap-changing operations are being performed, and further dispensing with operating means for the aforementioned current-carrying shunting switches. The aforementioned trigger pulse generators are controlled to supply the required trigger pulses not only during steady state periods, but also when a non-current-carrying movable contact of the selector switch separates from its cooperating fixed contact in order to select another tap of the tapped transformer winding.

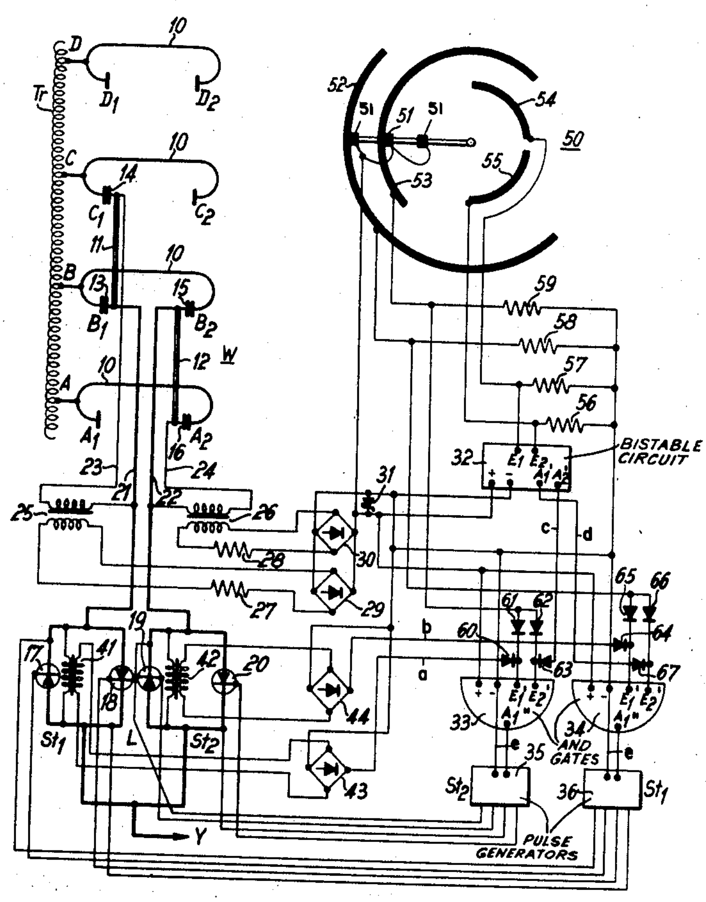

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FIG. 1

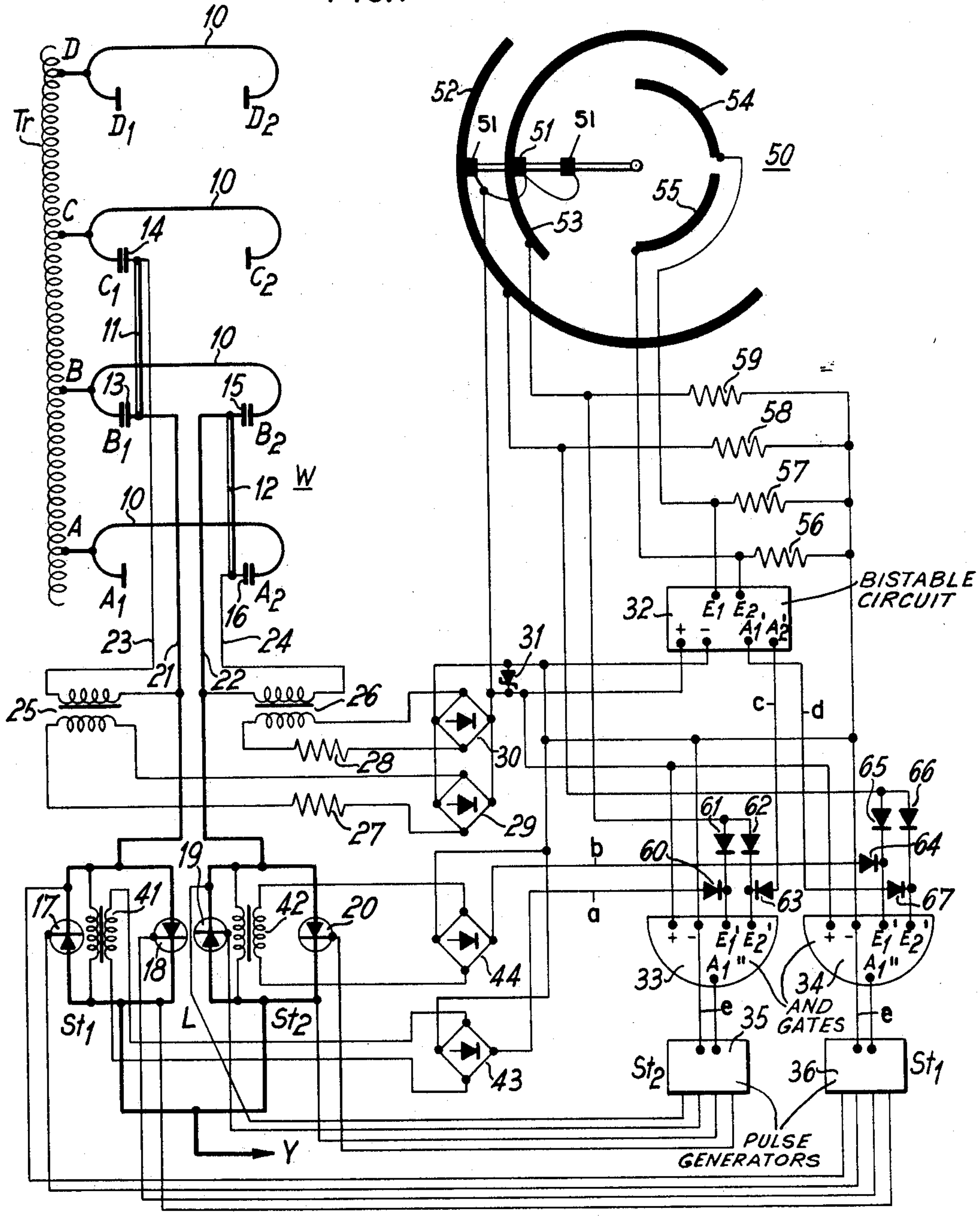

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FIG. 2

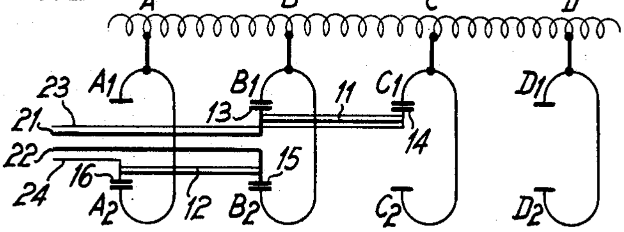

FIG. 3

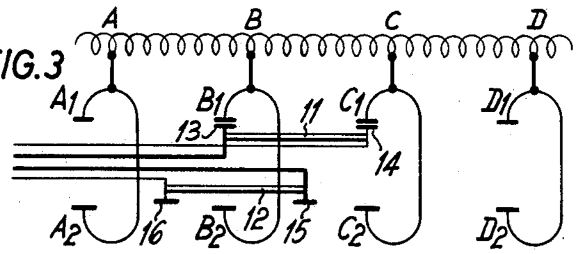

FIG. 4

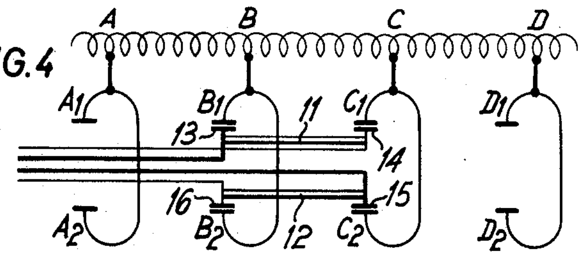

FIG. 5

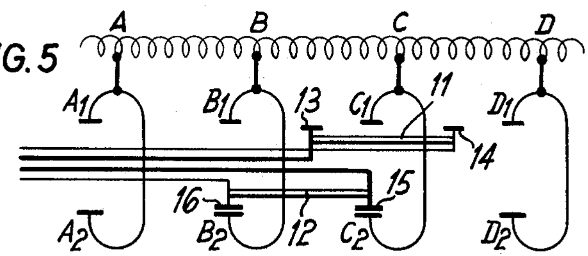

FIG. 6

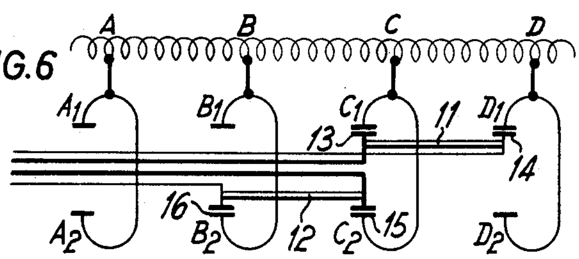

FIG. 7

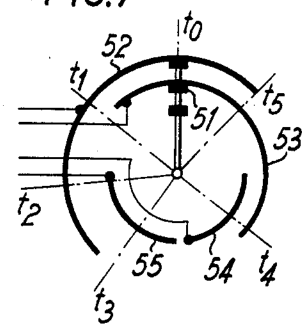

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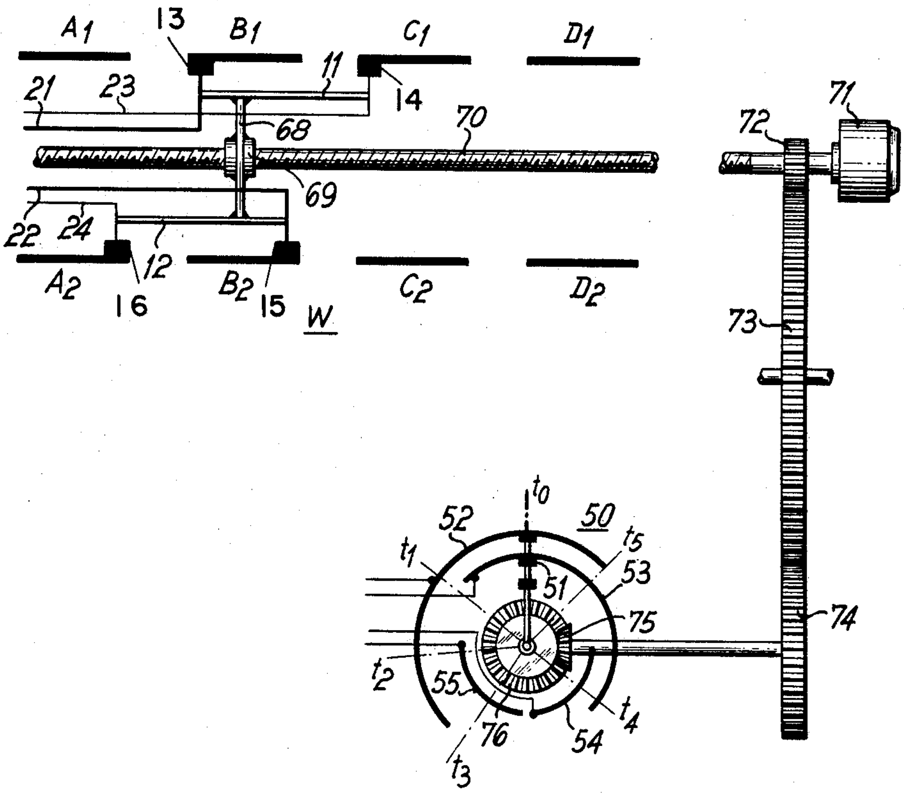
FIG. 8



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TAP-CHANGING REGULATING TRANSFORMER WITH SOLID-STATE CIRCUITRY

BACKGROUND OF INVENTION

This invention relates to tap-changing regulating transformers of the character more fully disclosed in U.S. Pat. No. 3,437,913 to M. Matzl, issued Apr. 8, 1969 for "Tapped Regulating Transformer Having Thyristor Transfer Switch Means" and in U.S. Pat. No. 3,466,530 to M. Matzl, issued Sept. 9, 1969 for "Logic-unit-controlled Thyristor Tap-changing Transfer Switch Having Trigger Impulse Amplifier." For a better appreciation of the following disclosure relating to a system which is an improvement of the systems disclosed in the two aforementioned patents reference may be had to the latter. The present invention includes subassemblies such as trigger pulse generators, and automatic circuitry for controlling said trigger pulse generators, which are disclosed in considerable detail in the aforementioned patents and which, hence, will be disclosed less specifically in what follows below.

Tap-changing transformers include a selector switch for selecting any desired tap among the plurality of taps with which a tapped transformer winding is provided, and they further include a transfer switch for disconnecting the load from one of the taps selected by the selector switch and connecting the load to another tap selected by the selector switch. In the systems of U.S. Pat. Nos. 3,437,913 and 3,466,530 the function of the transfer switch is performed by two triggerable parallel connected solid-state circuits, e.g. thyristor circuits (St_1 and St_2). Each of the aforementioned solid-state circuits is normally shunted by a current-carrying mechanical shunting switch (3,4). The aforementioned shunting switches carry the load currents as long as the system is in a steady state, and the thyristor circuits carry the load current only during the transient conditions of tap changes.

The tap-changing system according to this invention does not require the aforementioned heavy shunting switches, and therefore does not require special drives therefor (illustrated in FIG. 4 of U.S. Pat. No. 3,437,913 and described in its context). In other words, the triggerable solid circuits of the tap-changing system embodying this invention perform the dual function of carrying the load currents during steady state conditions, i.e. when and while the load is connected to one and the same tap of a tapped transformer winding, and also during transient conditions, i.e. during periods of time when the load is switched from one to another tap of a tapped transformer winding.

Another aspect relevant to the present invention is the particular source of energy for triggering the solid-state switching circuitry. Generally an insulating transformer is used to supply the energy required for triggering the solid-state switching circuitry. Such a transformer is relatively bulky and costly, particularly if the difference of potential is considerable. The capacity of the constituent parts of an insulating transformer results in capacitive currents which may adversely affect the control function of the insulating transformer. In the tap-changing system embodying this invention the energy required for triggering the solid-state circuitry is derived from the taps of the tapped transformer winding in such a way that the flow of energy is uninterrupted, i.e. is not interrupted when the current-carrying contact of the selector switch are separated preparatory to a change of taps.

SUMMARY OF INVENTION

A tapped regulating transformer embodying this invention includes a tapped transformer winding having a plurality of taps. It further includes a selector switch having a plurality of pairs of fixed contacts of which each pair is conductively connected to one of said plurality of taps. Each of said plurality of pairs of fixed contacts has a predetermined equal spacing from any contiguous pair of said plurality of pairs of contacts. The selector switch further has a pair of movable contact members each including a pair of movable contacts. One contact of each of said plurality of pairs of fixed contacts is arranged in a first surface, and said one contact of each of said plurality of pairs of fixed contacts forms a first group of fixed contacts. The other contact of each of said plurality of pairs of fixed contacts is arranged in a second surface parallel to said first surface and said second contact of each of said plurality of pairs of fixed contacts forms a second group of fixed contacts. The pair of movable contacts of each of said pair of movable contact members has a fixed spacing which is equal to said predetermined equal spacing of each of said plurality of pairs of fixed contacts. The movable contacts of one of said pair of movable contact members are arranged to engage selectively the fixed contacts of said first group of contacts, and the pair of movable contacts of the other pair of contact members are arranged to engage selectively the fixed contacts of said second group of contacts. The selector switch is further provided with means for selectively moving the pair of movable contact members parallel to said first surface and said second surface to cause said pair of movable contacts of one of said pair of contact members to engage selectively fixed contacts of said first group of contacts and to cause said pair of the other of said pair of contact members to engage selectively fixed contacts of said second group of contacts. The system further includes a pair of triggerable solid-state tap-changing circuits and a pair of control transformers. First conductor means connect conductively one of said pair of movable contacts of each of said pair of movable contact members to one of said pair of tap-changing circuits, and second conductor means connect conductively the other of said pair of movable contacts of each of said pair of contact members to one of said pair of control transformers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram of a complete system embodying this invention;

FIGS. 2 to 6, inclusive, show the tapped transformer winding of FIG. 1 and the selector switch of FIG. 1 in various relative positions involved in a tap-changing operation;

FIG. 7 shows diagrammatically an auxiliary switching device included in the circuit diagram of FIG. 1 and indicates the various switching positions of the former involved in a tap-changing operation, the representation of this switching device in FIG. 7 being angularly displaced as a matter of convenience in regard to its representation in FIG. 1; and

FIG. 8 is a diagrammatic representation of a gear drive for operating the selector switch of FIGS. 1—6, and for operating the auxiliary switching device of FIGS. 1 and 7.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to the drawings, reference character Tr has been applied to generally indicate a transformer winding having taps A, B, C, D, reference character W has been applied to generally designate a selector switch for selecting one of the taps A, B, C, D of winding Tr, and reference character L has been applied to generally designate a transfer switch for effecting tap changes under load. Selector switch W includes the fixed contacts A_1, B_1, C_1, D_1; A_2, B_2, C_2, D_2. Contacts A_1, B_1, C_1 and D_1 are arranged in a first surface or plane and contacts A_2, B_2, C_2 and D_2 are arranged in a second surface or plane parallel to said first surface or plane. Leads **10** interconnect conductively contacts A_1 and A_2; B_1 and B_2; C_1 and C_2; D_1 and D_2. Contacts A_1 and A_2 are conductively connected to tap A, contacts B_1 and B_2 are conductively connected to tap B, contacts C_1 and C_2 are conductively connected to tap C, and contacts D_1 and D_2 are conductively connected to tap D. Selector switch W further includes two pairs of movable contacts **13,14** and **15,16**, respectively. Tie member or contact member **11** integrates contacts **13,14** into a structural unit, and tie member or contact member **12** integrates contacts **15,16** into a structural unit. Structural unit **11, 13, 14** is arranged in the same plane as fixed contacts A_1, B_1, C_1 and D_1 and structural unit **12, 15, 16** is arranged in the same plane as contacts A_2, B_2, C_2 and D_2. Tie members or contact members **11,12** establish a fixed spacing between movable contacts 13,14 and 15,16, respectively, which spacing is equal to the spacing of contacts A_1, B_1, C_1 and D_1, and the spacing between contacts A_2, B_2, C_2 and D_2, respectively. As shown in FIG. 1 movable contacts 13 and 14 are in engagement with fixed contacts B_1 and C_1 arranged in the same surface or plane as contacts 13 and 14 and movable contact 15 and 16 are in engagement with fixed contacts B_2 and A_2 arranged in the same surface or plane as contacts 15 and 16.

The transfer switch L includes a pair of circuits, or networks, St_1 and St_2 which are connected in parallel. Circuit or network St_1 includes a pair of back-to-back or inverse parallel connected thyristors 17,18, and circuit or network St_2 includes a pair of back-to-back or inverse parallel connected thyristors 19,20. Reference characters 25 and 26 have been applied to designate a pair of control transformers each having a primary winding and a secondary winding. Lead or conductor means 21 connects conductively movable contact 13 to one of the terminals of circuit or network St_1, and to one of the terminals of the primary winding of control transformer 25. Lead or conductor means 23 conductively connects movable contact 14 to the other terminal of the primary winding of control transformer 25. Lead or conductor means 22 connects conductively the movable contact 15 to one of the terminals of circuit of network St_2, and to one of the terminals of the primary windings of control transformer 26. Lead or conductor means 24 connects conductively movable contact 16 to the other of the terminals of the primary winding of control transformer 26. It follows from the above that in the stationary state of selector switch W shown in FIG. 1 the voltage prevailing between contiguous taps B,C of tapped winding Tr is applied to the primary winding of transformer 25, and the voltage between contiguous taps B,A of transformer Tr is applied to the primary winding of transformer 26.

Reference character 32 has been applied in FIG. 1 to generally indicate a bistable circuitry, reference characters 33 and 34 have been applied to generally indicate a pair of AND gates, and reference characters 35,36 have been applied to a pair of pulse generators for generating trigger pulses for thyristors 17,18 and 19,20, respectively. The above components 32, 33, 34, 35, 36 form part of the control means of the tap-changing circuitry St_1 and St_2. These components are energized by the secondary windings of control transformers 25,26 by the intermediary of resistors 27,28 and rectifiers 29,30. The Zener diode 31 is arranged in the output circuits of rectifiers 29,30 to limit the output voltage thereof.

A transformer 41 having a primary winding and a secondary winding is operatively related to circuit St_1, its primary winding being connected in parallel with thyristors 17,18. Another transformer 42 having a primary winding and a secondary winding is operatively related to circuit St_2, its primary winding being connected in parallel with thyristors 19,20. The output of the secondary winding of transformer 41 energizes the bridge rectifier 43 to which the secondary winding of transformer 41 is conductively connected, and the output of the secondary winding of transformer 42 energizes the bridge rectifier 44 to which the secondary winding of transformer 42 is conductively connected. Transformer 41 and bridge rectifier 43 are first voltage sensing device sensing the voltage across thyristors 17,18 in terms of an analog DC output. Transformer 42 and bridge rectifier 44 are a second voltage sensing device sensing the voltage across thyristors 19,20 in terms of an analog DC output. The DC outputs of the above voltage sensing devices are an indication whether or not circuits St_1 and St_2 are blocked at any given moment. This information is supplied to AND gates 33 and 34, respectively, by leads *a* and *b*.

Reference character 50 has been applied to generally indicate an auxiliary rotary switching device, or drum-type auxiliary switch. Switching device 50 includes sliding contacts 51 sliding alternatingly on coaxial or concentric contact surfaces 52, 53, 54 and 55. As will be explained below more in detail in connection with FIG. 8 the tie bars 11,12 for contacts 13,14 and 16,15, respectively, and contacts 51 have a common drive system so as to move simultaneously. Switching device 50 is a timing switch and emits control signals which are precisely timed to achieve their intended function or purpose.

The bistable circuitry 32 has two input terminals marked E_1 and E_2, two input terminals marked + and − and two output terminals marked A_1' and A_2'. Each of the AND gates 33 and 34 has two input terminals marked E_1' and E_2', two input terminals marked + and −, and one output terminal marked A_1''. The output terminal A_1' of bistable circuitry 32 is conductively connected by a lead *d* to the input terminal E_2' of AND gate 34, and the output terminal A_2' of bistable circuitry 32 is conductively connected by a lead *c* to the input terminal E_2' of AND gate 33. A lead including resistor 59 connects conductively contact surface 53 to input terminal − of AND gate 34. Similarly a lead including resistor 58 and conductively connects contact surface 52 to the input terminal − of AND gate 34, a lead including resistor 57 connects conductively contact surface 54 to the − input terminal of AND gate 34, and a lead including resistor 56 connects conductively contact surface 55 to the − input terminal of AND gate 34. Leads including diodes 61,62 conductively connect contact surface 53 to the input terminals E_1' and E_2' of AND gate 33. A lead including the diode 60 connects conductively a DC terminal of bridge rectifier 43 to the input terminal E_1' of AND gate 33. Diode 63 is arranged in a lead conductively connecting the output terminal A_2' of bistable circuitry 32 to the input terminal E_2' of AND gate 33. The diode 64 is arranged in lead *b* conductively connecting one of the DC terminals of bridge rectifier 44 to the input terminal E_1' of AND gate 34. Similarly diode 65 is arranged in a lead conductively connecting contact surface 52 to input terminal E_1' of AND gate 34, diode 66 is arranged in a lead conductively connecting contact surface 52 to terminal E_2' of AND gate 34, and diode 67 is arranged in a lead conductively connecting output terminal A_1' of bistable circuitry 32 to input terminal E_2' of AND gate 34.

The input terminals E_1, E_2 of bistable circuitry 32 are conductively connected to contact surfaces 54 and 55 of switching device 50. The input terminals +, − of bistable circuitry 32 are conductively connected by leads to the DC output terminals of the aforementioned voltage-sensing rectifier bridges 29,30 and the aforementioned Zener diode 31 is shunted across the input terminals +, − of bistable circuitry 32. The DC output terminals of the aforementioned voltage-sensing rectifier bridges are further conductively connected by leads to the input terminals +, − of AND gates 33 and 34.

Pulses derived from the output terminals A_1'' of AND gates 33,34 control the pulse generators 35,36 and the latter trigger thyristors 17,18 and 19,20, respectively, and thus control the flow of electric currents through circuits St_1 and St_2, respectively. Pulse generators 35,36 have negative input terminals conductively connected by leads *e* to the negative input terminals − of AND gates 33,34. The reference character St_1 has been applied adjacent pulse generator 36 to indicate that the output of the latter controls the firing of thyristors 17,18 of circuit St_1 and the reference character St_2 has been applied adjacent pulse generator 35 to indicate that the output of the latter controls the firing of thyristors 19,20 of circuit St_2.

In FIG. 1 reference character Y has been applied to indicate an outgoing line connected to the lower terminals of circuits St_1 and St_2 and connecting these terminals to a load not shown.

The above-described tap-changing system operates as follows:

Assuming that the selector switch W is initially in the position shown in FIGS. 1 and 2. In that position the movable contacts 13 and 15 of the selector switch W are in engagement with the fixed contacts B_1 and B_2 of the latter. The movable contact 14 of the selector switch W is in engagement with the fixed contact C_1 thereof. Hence the primary winding of control transformer 25 is energized by the intermediary of leads 21,23 by the voltage prevailing between the contiguous taps B and C of transformer winding Tr. The movable contact 16 of the selector switch W engages its fixed contact A_2. Therefore the primary winding of control transformer 26 is energized by the intermediary of leads 22,24 by the voltage prevailing between the contiguous taps B and A of transformer winding Tr. The control transformers 25,26 energize the bridge rectifiers 29,30 whose DC output terminals are connected in parallel energizing bistable circuitry 32 and the two AND gates 33,34.

Any tap-changing signal—such as a signal to change from tap B to tap C—initiates a movement of tie member 12 with its movable contacts 15,16 in the direction of the fixed contacts which are conductively connected with the tap to which one intends to change. In the instant case this is the direction from fixed contact B_2 to fixed contact C_2. This phase or step in a tap-changing operation has been illustrated in FIG. 3. The aforementioned motion of tie member or contact member 12 with its contacts 15,16 has no effect upon the energization of transformer 25. Simultaneously with the movement of tie member or contact member 12 sliding contacts 51 of rotary switch 50 are moved by their common drive means. The movement of slide contacts 51 is counterclockwise as seen in FIG. 1 and results in a disengagement of slide contacts 51 from their cooperating contact surface 53. This position has been indicated in FIG. 7 as t_1. The separation of contacts 51,53 causes blocking of impulse generator 35 by the intermediary of AND gate 33. When switch 50 reaches the position indicated in FIG. 7 as t_2 the movable contacts 15 and 16 on tie member or contact member 12 are still out of engagement with any of their cooperating fixed contacts. However, the movable sliding contacts 51 now engage both contact surfaces 52 and 55. As a result, a voltage is applied to resistor 56 and to the input terminal E_2 of bistable circuitry 32. Consequently bistable circuitry 32 assumes its state wherein there is a voltage at its output terminal A_1'. Hence there is also a voltage at the input terminal E_2' of AND gate 34.

As the movement of tie member or contact member 12 and its contacts 15,16 progresses, movable contact 15 engages fixed contact C_2 and movable contact 16 engages fixed contact B_2. In that position of tie member or contact member 12 circuit St_1 still carries the full load current of a load connected to outgoing line Y, and the voltage prevailing between taps B,C prevails across circuit or network St_2. Hence transformer 42 is energized and rectifier 44 transmits a DC signal to the input terminal E_1' of the AND gate 34. Consequently a voltage is applied to both input terminals E_1' and E_2' of AND gate 34. This condition prevails even if sliding contacts 51 of the switching device 50 come out of engagement with contact surface 52. The position when the slide contacts 51 of switching device 50 come out of engagement with contact surface 52 has been indicated in FIG. 7 as position t_3.

As the movement of slide contacts 51 in counterclockwise direction progresses slide contacts 51 engage the contact surface 54. At this time the load current is commutated from circuit St_1 to circuit St_2 and from tap B to tap C of transformer winding Tr. This commutation occurs at the first current zero following engagement of contact surface 54 by one of slide contacts 51. When this occurs bistable circuitry 32 applies a voltage derived from output terminal A_2' to the input terminal E_2' of the AND gate 33. Furthermore a voltage is applied to the input terminal E_1' of AND gate 33 by transformer 41 and bridge rectifier 43 since the voltage prevailing between taps B and C prevails at this point of time across the terminals of the primary winding of transformer 41.

As the counterclockwise movement of slide contacts 51 of switching device 50 further progresses, one of the sliding contacts 51 engages the contact surface 53. This position of slide contacts 51 has been indicated in FIG. 7 as position t_4. As a result of the engagement of contact surface 53 by slide contacts 51 a voltage is applied to the input terminals E_1' and E_2' of AND gate 33. The sliding contacts 51 remain in engagement with contact surface 53 up to and after the point of time when they reach the initial position thereof indicated in FIG. 7 as position t_0. Consequently the circuit St_2 keeps carrying current.

In the interval of time when sliding contacts 51 move from their position t_4 to their position t_5—both indicated in FIG. 5—the tie member or contact member 11 with its movable contacts 13 and 14 moves from left to right as seen in FIGS. 4 and 5, and movable contacts 13 and 14 disengage from fixed contacts B_1 and C_1. This has been shown in FIG. 5. At this point of time the control circuit proper is energized by control transformer 26. When sliding contacts 51 reach the position t_5 of FIG. 7 one of sliding contacts 51 reengages contact surface 52. As a result, the AND gate 34 ceases to block pulse generator 36 so that the latter transmits trigger pulses to the thyristors 17,18 in circuit or network St_1.

Tie member or contact member 11 continues its travel from left to right as seen in FIGS. 2—6 until its movable contacts 13,14 engage the fixed contacts C_1,D_1 of selector switch W. This is shown in FIG. 6. At the point of time shown in FIG. 6 circuit St_1 is made conductive and circuits St_1 and St_2 now share the current flowing from tap C of winding Tr and outgoing line Y to the load supplied by the transformer. Sliding contacts 51 remain in their initial position t_0 ready to perform additional tap-changing operations. If this tap-changing operation is a change from tap C to tap D, such operation involves but a repetition of the sequence of steps previously described. On the other hand, if such tap-changing operation is a change from tap C to tap B of winding Tr, sliding contacts 51 are pivoted in the opposite or clockwise direction, and tie members or contact members 11 and 12 are moved sequentially from right to left as seen in FIGS. 2 to 6, i.e. in the direction of tap B of winding Tr.

It will be apparent from the above that both circuits St_1 and St_2 and their thyristors 17,18; 19,20 equally share the load current during steady state periods. The thyristors 17,18 and 19,20 carry the full load current only during extremely short intervals of time when a tap-changing operation is performed. The fact that thyristors 17,18 and 19,20 are current-carrying almost all of the time is a significant advantage of the system embodying this invention over comparable prior art systems since this fact makes it possible to provide circuits St_1 and St_2 with thyristors of relatively limited current-carrying capacity.

It will be further apparent from the above that the particular design of selector switch W results in that the energy supply of the control circuitry derived from the taps of tapped winding Tr is never interrupted. To be more specific, the control circuitry of the system is energized by the voltage prevailing between contiguous taps of tapped winding Tr at times when both circuits St_1, St_2 are current-carrying as well as at times when but one of these circuits is current-carrying.

It is apparent that the circuitry of FIG. 1 could be readily modified by substituting a first triac for thyristors 17,18 and a second triac for thyristors 19,20. The term triggerable solid-state tap-changing circuit is intended to encompass generally thyristor and triac circuits St_1 and St_2.

The mechanical timing switch 50 shown in FIGS. 1 and 7 is but a preferred form of timing means for performing all of the steps involved in a tap-changing operation in the proper sequence. The mechanical timing switch 50 of FIGS. 1 and 7 could be replaced by conventional magnetic tape timer, or by conventional numerical control means, e.g. a perforated rotatable disc and photoelectric cells operatively related to the same.

The table below makes the steps involved in a tap-changing operation as they have been described above particularly evident.

Figure	Selector switch W tap contacts				Control transformers		Voltage-sensing transformers		Timing switch	Bistable	AND gates		Pulse generators		Solid state circuits	
	13	14	15	16	25	26	41	42	50	circuit 32	33	34	35	36	St_2	St_2
2	B_2	C_1	B_2	A_2	BC	AB	0	0	t_0; 52.+; 53.+	A_2+	On	On	On	On	On	On.
3	B_1	C_1	0	0	BC	0	0	0	t_1; 52.+; 53.0	A_2+	Off	On	Off	On	Off	On.
3	B_1	C_1	0	0	BC	0	0	0	t_2; 52.+; 55.+	A_2+	Off	On	Off	On	Off	On.
4	B_1	C_1	C_2	B_2	BC	BC	0	[1]	t_3; 52.0; 55.+	A_2+	Off	On	Off	On	Off	On.
4	B_1	C_1	C_2	B_2	BC	BC	0	[1]	t_3–t_4; 55.0; 54.+	A_2+	Off	Off	Off	Off	Off	On.
4	B_1	C_1	C_2	B_2	BC	BC	[1]	0	t_4; 54.+; 53.+	A_2+	On	Off	On	Off	On	Off.
5	0	0	C_2	B_2	0	BC	0	0	t_4–t_5; 54.0; 53.+	A_2+	On	Off	On	Off	On	Off.
5	0	0	C_2	B_2	0	BC	0	0	t_5; 52.+; 53.+	A_2+	On	On	On	On	On	On.
6	C_1	D_1	C_2	B_2	CD	BC	0	0	t_0; 52.+; 53.+	A_2+	On	On	On	On	On	On.

[1] Energized.

Referring now to FIG. **8**, the same reference characters have been applied in that FIG. as in previous FIGS. to indicate like parts. The selector switch W includes fixed contacts A_1, A_2; B_1, B_2; C_1, C_2; and D_1, D_2 and cooperating movable contacts **13,14**; **15,16** supported by tie members **11** and **12**, respectively. Electric motor **71** operates screwed spindle **70** supporting an internally screw-threaded nut **69**. Transverse operating bar **68** is an integral part of nut **69**. The tie members or contact members **11,12** are affixed to the radially outer ends of operating bar **68**. Rotation of screwed spindle **70** results in a movement of parts **68, 69, 11** and **12** in a direction longitudinally thereof. Consequently movable contacts **13,14** and **15,16** are also moved in a direction longitudinally of spindle **70**. Conductor **21** is conductively connected to movable contact **13**, conductor **23** is conductively connected to movable contact **14**, conductor **22** is conductively connected to movable contact **15** and conductor **24** is conductively connected to movable contact **16**. Conductors **21, 22, 23, 24** form part of the circuitry of FIG. **1** as shown in FIG. **1**. The interconnections **10** between the fixed contacts of the selector switch W shown in FIG. **1** have been deleted in FIG. **8** for the sake of increased clarity.

The shaft of motor **71** supports a pinion **72** meshing with spur gear **73**. Spur gear **73** meshes with spur gear **74** whose shaft supports a bevel gear **75** in meshing engagement with bevel gear **76**. The latter operates the rotatable contacts **51** of timing switch **50**. The aggregate gear ratio of gear train **72, 73, 74, 75, 76** is selected in such a way that contacts **51** perform a full revolution in the time interval when contacts **13,14** and **15,16** move one step, e.g. from B_1 and C_1 to C_1 and D_1 and from A_2 and B_2 to B_2 and C_2. This applies for the specific embodiment of the invention shown in FIG. **8**. Speaking more generally, the selector switch W and the timing switch **50** must be driven by transmission means of such a nature that their velocities are linearly related. Thus the velocities of operating bar **68** and of bevel gear **76** and slide contacts **51** are linearly proportional.

The fixed contacts A_1, A_2; B_1, B_2, etc. of selector switch W are, and may be referred to, as tap contacts because each pair of them is directly connected to one of the taps of the tapped transformer winding and is at the same potential as the tap to which the particular pair of contacts is conductively connected. The parallel circuits St_1 and St_2 are, and may be referred to as, AC circuit branches controlled by triggerable solid-state devices **17,18; 19,20**. The AC circuit branches St_1, St_2 have a common output terminal to which the outgoing load line Y is conductively connected. Since the spacing members **11** and **12** support contacts **13,14** and **15,16** they are in effect contact carriers and may be referred-to as such.

It will be understood that although but one preferred embodiment of the invention has been illustrated and described in detail, the invention is not limited thereto. It will also be understood that the structure and the circuitry illustrated and described may be modified without departing from the spirit and scope of the invention.

I claim:

1. A tap-changing regulating transformer with solid-state circuitry for performing tap-changing operations including:

a. a tapped transformer winding having a plurality of taps;

b. a selector switch having a plurality of pairs of fixed contacts each conductively connected to one of said plurality of taps, each of said plurality of pairs of fixed contacts having a predetermined equal spacing from any contiguous pair of said plurality of pairs of fixed contacts, and said selector switch further having a pair of movable contact members each including a pair of movable contacts, one contact of each of said plurality of pairs of fixed contacts being arranged in a first surface and said one contact of each of said plurality of pairs of fixed contacts forming a first group of fixed contacts, and the other contact of each of said plurality of pairs of fixed contacts being arranged in a second surface parallel to said first surface and said other contact of each of said plurality of pairs of fixed contacts forming a second group of fixed contacts, said pair of movable contacts of each of said pair of movable contact member having a fixed spacing equal to said predetermined equal spacing of said plurality of pairs of fixed contacts, said pair of movable contacts of one of said pair of movable contact members being arranged to engage selectively the fixed contacts of said first group of contacts and said pair of movable contacts of the other of said pair of contact member being arranged to engage selectively the fixed contacts of said second group of contacts;

c. means for selectively moving said pair of movable contact members parallel to said first surface and said second surface to cause said pair of movable contacts of one of said pair of contact members to selectively engage fixed contacts of said first group of contacts and to cause said pair of movable contacts of the other of said pair of contact members to engage selectively fixed contacts of said second group of contacts;

d. a pair of triggerable solid-state tap-changing circuits;

e. a pair of control transformers each having a pair of terminals;

f. first conductor means connecting conductively one of said pair of movable contacts of each of said pair of movable contact members to one of said pair of tap-changing circuits and to one of said pair of terminals of each of said pair of control transformers; and

g. second conductor means connecting conductively the other of said pair of movable contacts of each of said pair of movable contact members to the other of said pair of terminals of each of said pair of control transformers.

2. A tap-changing regulating transformer as specified in claim 1 including:

a. automatically controlled pulse generator means for triggering said pair of tap-changing circuits;

b. means for controlling said pulse generator means including said pair of control transformers, a logic circuitry, a bistable circuitry and a timing switch; and

c. means for operating said pair of movable contact members and said timing switch at fixedly related velocities.

3. A tap-changing regulating transformer as specified in claim 2 wherein said timing switch includes fixed circular coaxial contacts and slide contacts rotatable about the center of said fixed contacts and movable into and out of engagement with said fixed contacts.

4. A tap-changing regulating transformer as specified in claim 3 wherein said pair of movable contact members is operated by a first transmission means and wherein said slide contacts are operated by a second transmission means and wherein said first transmission means and said second transmission means are operated by a common motor means.

5. A tap-changing regulating transformer with solid-state circuitry for performing tap-changing operations including:

a. a tapped transformer winding having a plurality of taps;
b. a selector switch operatively related to said transformer winding having pairs of tap contacts, each pair of said pairs of tap contacts being conductively connected to one of said plurality of taps, and each pair of said pairs of tap contacts having a fixed spacing from any contiguous pair of said pairs of tap contacts, said selector switch further including a first pair of relatively movable contacts having a fixed spacing equal to said fixed spacing of said pairs of tap contacts and arranged to cooperate with one tap contact of each said pairs of tap contacts and a second pair of relatively movable contacts having a fixed spacing equal to said fixed spacing of said pairs of tap contacts and arranged to cooperate with the other tap contact of each of said pairs of tap contacts;
c. operating means for establishing selectively relative movements between said first pair of relatively movable contacts and said pairs of tap contacts and between said second pair of relatively movable contacts and said pairs of tap contacts to select among said plurality of taps;
d. a transfer switch including a first triggerable AC circuit branch having one input terminal conductively connected to one contact of said first pair of relatively movable contacts and a second triggerable AC circuit branch having an input terminal conductively connected to one contact of said second pair of relatively movable contacts, said first AC circuit branch and said second AC circuit branch having a common output terminal;
e. a pair of trigger pulse generators, one of said pair of generators being operatively related to said first circuit branch to trigger said first circuit branch and the other of said pair of generators being operatively related to said second circuit branch to trigger said circuit branch; and
f. control means for said pair of generators to cause said pair of generators to trigger said first circuit branch and said second circuit branch in a tap-changing sequence, and said control means further including means for activating said pair of generators subsequent to any tap-changing sequence to connect said first circuit branch and said second circuit branch in parallel following any tap-changing sequence.

6. A tap-changing regulating transformer as specified in claim 5 including:

a. a pair of control transformers, one of said pair of control transformers being conductively connected to said first pair of relatively movable contacts and the other of said pair of control transformers being conductively connected to the other of said pair of relatively movable contacts;
b. a pair of voltage-sensing transformers, one of said pair of voltage-sensing transformers being connected across said first circuit branch and the other of said pair of voltage-sensing transformers being connected across said second circuit branch;
c. a timing switch, a bistable circuitry and a pair of AND gates for controlling the operation of said pair of generators;
d. rectifier means in the output circuits of said pair of control transformers and rectifier means in the output circuits of said pair of voltage-sensing transformers for energizing said timing switch, said bistable circuitry and said pair of AND gates; and
e. a common drive means for said first pair of relatively movable contacts, said second pair of relatively movable contacts and said timing switch to move said first pair of relatively movable contacts, said second pair of relatively movable contacts and said timing switch in the required sequence at linearly related velocities.

7. A tap-changing regulating transformer as specified in claim 5 wherein said first circuit branch and said second circuit branch each include a pair of inverse parallel connected thyristors.

8. A tap-changing regulating transformer with solid-state circuitry to perform tap-changing operations including:

a. a tapped transformer winding having a plurality of taps;
b. a selector switch including a first group of aligned fixed contacts having a predetermined spacing and a second group of aligned fixed contacts having a predetermined spacing, each contact of said second group being juxtaposed to one contact of said first group and each pair of juxtaposed contacts being conductively connected to a common tap forming part of said plurality of taps, said selector switch further including a first pair of movable contacts having the same spacing as the contacts of said first group and being movable along a line defined by the contacts of said first group into and out of engagement with the contacts of said first group and said selector switch further including a second pair of movable contacts having the same spacing as the contacts of said second group and being movable along a line defined by the contacts of said second group into and out of engagement with the contacts of said second group;
c. a first AC circuit branch including triggerable semiconductor switch means, said first circuit branch having an input terminal conductively connected to one of said first pair of movable contacts;
d. a second AC circuit branch including triggerable semiconductor switch means, said second circuit branch having an input terminal conductively connected to one of said second pair of movable contacts;
e. a first control transformer conductively connected to said first pair of movable contacts;
f. a second control transformer conductively connected to said second pair of movable contacts;
g. a first voltage-sensing transformer shunted across said first circuit branch;
h. a second voltage-sensing transformer shunted across said second circuit branch;
i. a pair of trigger pulse generators, one for triggering said semiconductor switch means in said first circuit branch and one for triggering said semiconductor switch means in said second circuit branch; and
j. control means for said pair of trigger pulse generators under the joint control of said first control transformer, said second control transformer, said first voltage-sensing transformer and said second voltage-sensing transformer, said control means including logic circuitry for simultaneously triggering said pair of trigger pulse generators upon termination of any tap-changing operation and restoration of steady state conditions to cause both said first circuit branch and said second circuit branch to be current carrying upon termination of any tap-changing operation and restoration of steady state conditions.

9. A tap-changing regulating transformer as specified in claim 8 including:

a. a timing switch, a bistable circuitry and a pair of AND gates for controlling the operation of said pair of trigger pulse generators; and
b. rectifier means in the output circuits of said first control transformer and of said second control transformer and rectifier means in the output circuits of said first voltage-sensing transformer and of said second voltage-sensing transformer for energizing said timing switch, said bistable circuitry and said AND gates.

10. A selector switch for tap-changing regulating transformers with solid-state circuitry for performing tap-changing operations including:

a. a first plurality of fixed aligned contacts having a predetermined spacing;

b. a first contact carrier movable along a trajectory defined by said first plurality of aligned contacts, said first contact carrier supporting a pair of movable contacts having the same spacing as the constituent contacts of said first plurality of contacts and being engageable with and separable from the constituent contacts of said first plurality of contacts;

c. a second plurality of fixed aligned contacts having a predetermined spacing, each contact of said second plurality of contacts being juxtaposed to one contact of said first plurality of contacts;

d. a second contact carrier movable along a trajectory defined by said second plurality of aligned contacts, said second contact carrier supporting a pair of movable contacts having the same spacing as the constituent contacts of said second plurality of contacts and being engageable with and separable from the constituent contacts of said second plurality of contacts;

e. conductor means conductively interconnecting each contact of said first plurality of contacts with a juxtaposed contact of said second plurality of contacts; and

f. two pairs of leads, one of said pairs of leads being conductively connected to said pair of movable contacts supported by said first contact carrier and the other of said pairs of leads being conductively connected to said pair of movable contacts supported by said second contact carrier.