

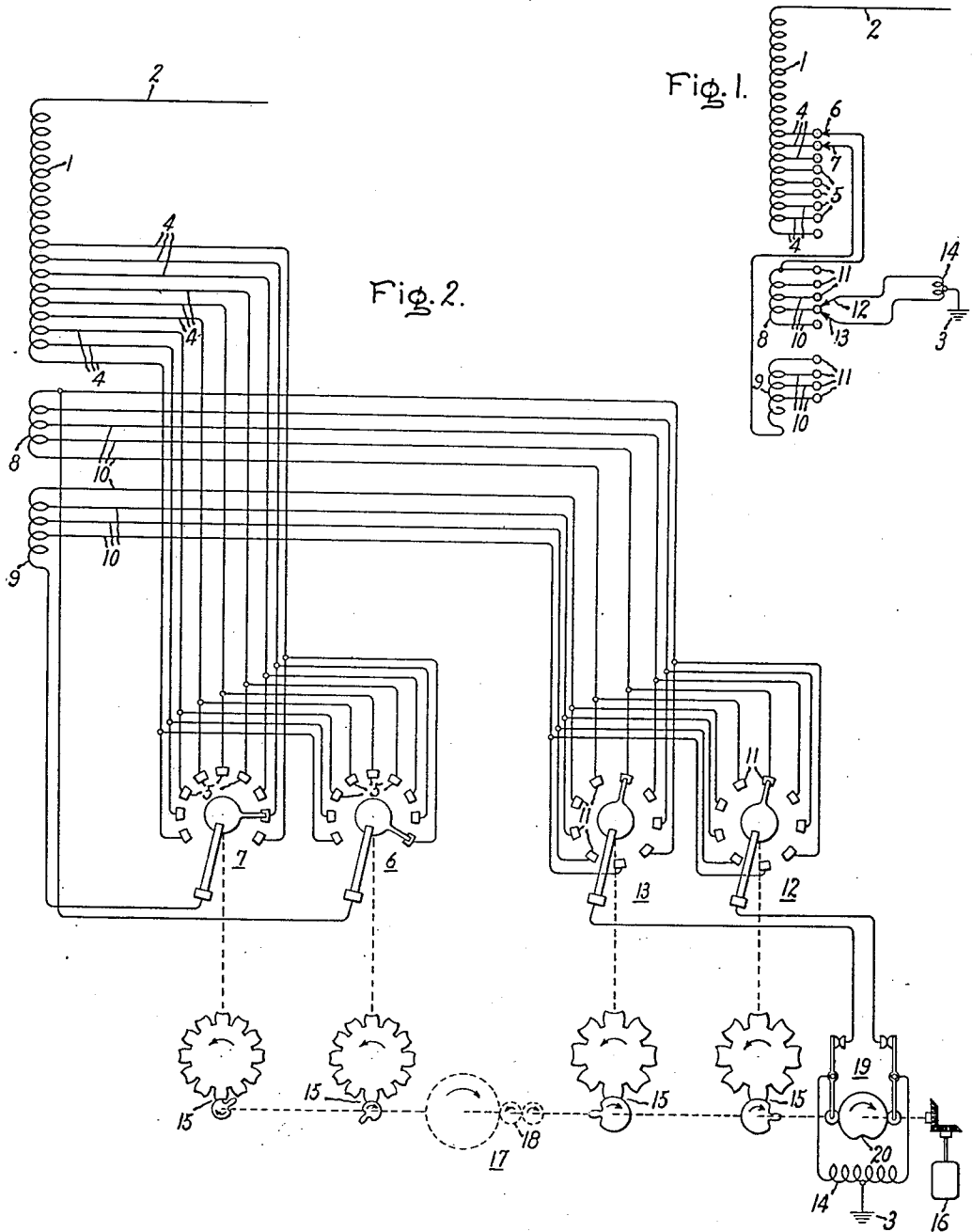
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TRANSFORMER TAP-CHANGING SYSTEM

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TRANSFORMER TAP-CHANGING SYSTEM

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9 Claims. (Cl. 171-119)

This invention relates to a method and apparatus for transformer tap-changing-under-load and more particularly to an improved vernier type load ratio control system.

By load ratio control is meant the control of the voltage ratio of a transformer under load by means of suitable tap-changing switches. A vernier load ratio control system differs from an ordinary load ratio control system in that a vernier winding is selectively connectable between taps on the main transformer winding and taps are changed on the vernier winding so as to give a plurality of intermediate steps or voltages between the voltages of the taps on the main transformer winding. By successively connecting the vernier winding across different pairs of main winding taps the number of voltage steps is many times greater than the actual number of taps employed. Thus, the number of steps is equal to the product of the number of pairs of taps on the main winding and the number of pairs of taps on the vernier winding instead of being equal merely to the sum of the number of taps on both windings.

In accordance with this invention I provide two insulated vernier windings and operate the tap-changing means on the main transformer and on the vernier windings in such a way that the main transformer tap-changing means is operated only when it is not carrying current. It can therefore be operated slowly and the usual switch or contactor for interrupting the current in the main tap-changing means before a tap-changing operation takes place can be eliminated.

An object of the invention is to provide a new and improved method and apparatus for transformer tap-changing-under-load.

Another object of the invention is to provide an improved and simplified vernier load ratio control circuit.

The invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, in which like reference characters designate the same elements in the two views, Fig. 1 illustrates diagrammatically an embodiment of the invention which may be manually operated, and Fig. 2 illustrates a complete automatic mechanism for carrying out my invention.

Referring now to the drawing, and more particularly to Fig. 1, there is shown therein a main transformer winding 1 which may, for example,

be one of the phase windings of the primary or the secondary of a transformer system having any number of phases. The circuit of this winding may be completed through a conductor 2 and ground 3. The winding 1 is provided with a plurality of taps 4 terminating in tap contacts 5. For engaging these tap contacts are a pair of main movable contacts 6 and 7.

A pair of insulated vernier windings 8 and 9 are connected respectively to the main movable contacts 6 and 7. These vernier windings may be mounted on the same core as the main winding 1 or they may be excited by a separate core if desired. They are each preferably, but not necessarily, provided with a plurality of taps 10 terminating in vernier tap contacts 11. Taps are changed on the vernier windings by means of a pair of movable vernier contacts 12 and 13 which are connected respectively to the terminals of a mid-tapped reactor 14 of conventional design for minimizing circulating current flow in the vernier winding. The mid-tap of reactor 14 is connected to ground 3.

The taps 4 on the main winding are preferably substantially equally electrically spaced so that the voltage between each adjacent pair of them is substantially equal. Similarly the taps 10 on the vernier windings are preferably substantially equally spaced so that the voltage between each adjacent pair of them is substantially equal. However, the voltage between adjacent vernier taps is less than the voltage between adjacent main taps. In addition, the sum of the voltages of the vernier windings 8 and 9 is preferably less than the voltage between adjacent taps on the main winding. This difference is preferably equal to the voltage between a pair of adjacent vernier taps 10.

The operation of Fig. 1 is as follows. If it is desired to connect more of the main winding 1 between conductor 2 and ground, vernier contact 13 is moved downwardly from the position shown. In this new position, the mid-tapped reactor 14 is connected between the two lowermost tap contacts on the vernier winding 8 and a circulating current flows in the reactor but this current is limited to a safe value by the reactance of the reactor. Next the contact 12 is moved downwardly to the same vernier tap contact to which movable vernier contact 13 is connected. This then connects the last contact 11 on the vernier winding 8 directly to ground through the two vernier contacts 12 and 13 and the two halves of reactor 14 in parallel. As there is no voltage across the reactor 14, there will be

no circulating current in it; and as the load current will divide equally between the two halves of the reactor, it will have substantially no effective reactance. The contacts 13 and 12 are then moved to the first contact on vernier winding 9 in the same step-close order, contact 13 leading and contact 12 following up and closing the step. It will be observed that when the vernier movable contacts are transferred from vernier 8 to vernier 9, the load current is transferred from movable main contact 6 to movable main contact 7.

For the first step in tap-changing described above, between the next to the last and the last tap contact on vernier winding 8, the voltage between these taps is added to the voltage of the top main tap contact on the main winding. When the contacts 13 and 12 make contact with the vernier tap contacts on the vernier winding 9, the voltage of the vernier winding 9 is subtracted from the voltage of the main tap contact to which the main movable contact 7 is connected. However, as the voltage of this latter main tap contact is greater than the voltage of the first or uppermost main tap contact, the change in voltage is the same for each step made on the vernier windings. When the vernier movable contacts 12 and 13 have moved down to one of the tap contacts on the vernier winding 9, the main movable contact 6, which now is carrying no current, is moved down into engagement with the same tap contact to which the main movable contact 7 is connected. This of course increases the voltage of the vernier winding 8 (with respect to line 2) by the tap to tap voltage of the main winding. When the vernier movable contacts 13 and 12 engage the lowermost vernier tap contact on the vernier winding 9, the next step is to move the vernier movable contact 13 into engagement with the topmost tap contact on the vernier winding 8 and then follow it up by making the same tap change with the movable contact 12. When this step is completed, the load current will flow through the movable main contact 6, and the movable main contact 7 will be idle. As main movable contacts 6 and 7 are both in engagement with the same main tap contact, the only voltage produced by this last vernier tap change is to raise the voltage by the tap to tap vernier voltage represented by the end turns on the vernier winding 9. The vernier movable contacts are then moved downwardly again over the tap contacts of the vernier winding 8, and when they reach one of the inner or central tap contacts the main movable contact 7 is moved down to the third main tap contact. The elements will now be in the same relative positions they occupy in Fig. 1 except that main movable contacts 6 and 7 have each been moved down one tap. This cycle of operation may be continued as long as desired and if it is desired to change the voltage in the opposite direction the operation is merely reversed, the vernier contacts moving up on the vernier contacts and the main movable contacts moving up on the main tap contacts in step-close relationship.

It will be observed that the main movable contacts 6 and 7 are only moved at times when the vernier movable contacts are in engagement with the vernier tap contacts on the vernier winding which is connected to the other main movable contact. Consequently, the main movable contacts are never called upon to break any current and they can be moved slowly from tap to tap and it is unnecessary to provide any additional

contactors or current interrupting means for these movable contacts.

As the sum of the voltages of the vernier windings 8 and 9 is less than the tap to tap voltage on the main winding by an amount which is equal to the vernier tap to tap voltage, it follows that, when the vernier tap-changing contacts 12 and 13 go from the lowermost tap contact on vernier winding 8 to the uppermost tap contact on vernier winding 9, the voltage change will be equal to the vernier tap to tap voltage. Consequently, so far as voltage changes in the main circuit are concerned all the vernier voltage steps will be substantially equal.

Another feature of the invention is that there will normally be no circulating current in the main winding when the main movable contacts 6 and 7 are in engagement with different main tap contacts 5. This is because the vernier windings 8 and 9 are insulated so that only when the vernier movable contacts 12 and 13 bridge the gap between the vernier windings 8 and 9 will it be possible for any circulating current to flow in the main winding 1.

In Fig. 2 the movable contacts 6, 7, 12 and 13 and the tap contacts 5 and 11 are arranged to form separate dial type switches or ratio adjusters. They are arranged to be operated in the proper sequence automatically by means of suitable mechanical movements shown by way of example as Geneva gear movements 15 operated by a common driving motor 16. The movable contacts 12 and 13 are continuously rotatable making one complete revolution corresponding to one complete tap-changing cycle in Fig. 1. As there are nine vernier tap contacts shown, the vernier tap-changing contacts 12 and 13 operate nine times as fast as the main tap changing means 6 and 7 so that a 9:1 gear reduction is interposed between the drive for the vernier tap changers 12 and 13 and the main tap changers 6 and 7. This is shown diagrammatically by reduction gearing 17 and an idler gear 18 has been inserted so that the direction of rotation of all of the Geneva gear movements will appear the same and thus render easier the understanding of the operation.

A contactor 19 driven by a cam 20 has also been provided for automatically interrupting the current through the vernier tap changers 12 and 13 before they make a tap-changing operation.

The operation of Fig. 2 is as follows: The parts in Fig. 2 are electrically in the same relative positions as they are shown in Fig. 1. When motor 16 is energized so as to drive the cams in the direction shown by the arrows, the left-hand contact of contactor 19 will first open, then the vernier tap changer 13 will be rotated one step in a counter-clockwise direction. Then the left-hand contacts of the contactor 19 will close. Next the right-hand contacts of contactor 19 will open and shortly thereafter the vernier tap changer 12 will make its follow-up motion and be rotated one step in a counter-clockwise direction. This cycle will be repeated until the vernier contacts 13 and 12 have been rotated step by step about one-half a revolution. They will then be connected to one of the inner taps of the vernier winding 9 and at about this time the main tap changer 6 will be moved one step in a counter-clockwise direction so as to make connection to the same tap to which the main tap changer 7 is connected. The operation then continues for about another half revolution of the vernier tap switches 12 and 13 and at about

this time the main tap changer 7 will advance one tap or step in a counter-clockwise direction. This cycle will then continue as long as desired and of course may be reversed at any time. The main tap changers 6 and 7 always operate when they are not carrying any current so that they may operate without any difficulty at one-ninth the speed of the vernier tap switches 12 and 13. While there have been shown and described particular embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of transformer tap-changing-under-load which comprises, first, providing a movable two-contact type main tap changer with a pair of insulated tapped vernier windings connected respectively to the main movable contacts; second, making successive main-circuit connections to the taps on one vernier winding and moving the movable contact connected to the other vernier winding during said successive connections; and, third, making successive main-circuit connections to the taps on the other vernier winding and moving the first movable contact during said second successive connections.

2. A transformer ratio adjusting system comprising, in combination, a main transformer winding provided with a plurality of main tap contacts, a pair of movable main contacts for successively engaging said main tap contacts, a pair of insulated vernier windings connected respectively to said main movable contacts, said vernier windings each having a plurality of vernier tap contacts, a movable vernier contact for successively engaging said vernier tap contacts, and means for so interlocking the motions of said movable contacts that a main movable contact is moved only when the movable vernier contact is engaging a vernier tap contact on the vernier winding which is connected to the other main movable contact.

3. A transformer tap-changing-under-load system comprising, in combination, a main transformer winding provided with a plurality of substantially equally electrically spaced main contacts, a pair of main movable contacts, means for causing said main contacts to make successive electrical connection to said main taps in step-close order whereby for one direction of operation one main contact leads in going from tap to tap and the other main contact makes the same tap change after the first one has completed it and before the first one makes a second tap change, a pair of insulated vernier windings on said main transformer, means for connecting a terminal of one vernier winding to one of said main movable contacts and for connecting a terminal of the other vernier winding to the other main movable contact, a plurality of substantially equally electrically spaced vernier taps on each of said vernier windings, the vernier tap to tap voltage being a fraction of the main tap to tap voltage and being substantially equal to the difference between the main tap to tap voltage and the sum of the vernier tap to tap voltages, vernier tap-changing means for sequentially making connection to said vernier taps without interrupting the circuit through said means, and means for interlocking said vernier tap-changing means with said main

movable contacts in such a way that each main movable contact is only moved from tap to tap when said vernier tap-changing means is in contact with a tap on the vernier winding which is connected to the other main movable contact.

4. A transformer tap-changing-under-load system comprising, in combination, a main transformer winding provided with a plurality of electrically spaced taps, a circuit which is completed through said main winding, two auxiliary windings, each one having at least two terminals, means to connect a terminal of one of said auxiliary windings selectively to one of said taps, means to connect a terminal of the other auxiliary windings selectively to one of said taps, and means to connect a conductor of said circuit selectively to a terminal of said auxiliary windings.

5. A transformer ratio adjusting system comprising, in combination, a main transformer winding equipped with taps, a circuit which is completed through said main winding, two auxiliary windings, connection changing means to connect said auxiliary windings selectively to a tap of said main winding, connection changing means to connect selectively said auxiliary windings to a conductor of said circuit, and means to so interlock the operations of said two connection changing means that the change of a connection through the first connection changing means is effected while the circuit of that connection is interrupted through said second connection changing means.

6. A transformer ratio adjusting system comprising, in combination, a main transformer winding equipped with a plurality of coarse tap steps, a circuit which is completed through said main winding, two auxiliary windings equipped with a plurality of fine tap steps, a ratio adjustor to connect selectively said auxiliary windings to a tap of said main winding, a ratio adjustor to connect a conductor of said circuit selectively to a tap of said auxiliary windings, and means for so interlocking the motions of said two adjustors that a current interruption due to a tap-changing takes place only in the adjustor operating on said fine tap steps.

7. A transformer tap-changing-under-load system comprising, in combination, a main transformer winding equipped with a plurality of electrically spaced tap contacts, a pair of main movable contacts for successively engaging said main tap contacts, a pair of auxiliary windings connected respectively to said main movable contacts and equipped with electrically spaced contacts, an auxiliary movable contact for successively engaging the contacts of said auxiliary windings, and means for so interlocking the motions of said main and auxiliary movable contacts that a main movable contact moves only when the auxiliary movable contact is in series circuit relation ship with the other main movable contact.

8. A transformer tap-changing-under-load system comprising, in combination, a main transformer winding equipped with a plurality of electrically spaced taps, two auxiliary windings, each one of said auxiliary windings having a voltage a fraction of the tap to tap voltage of said main winding, means to connect one end of one of said auxiliary windings selectively to one of said taps with the voltages of said main winding and said auxiliary winding in additive relationship, means to connect one end of the other auxiliary winding selectively to one of said taps with the voltages of said winding and said other auxiliary winding in subtractive relationship, and means to

complete a circuit for said main winding through said auxiliary windings selectively.

9. The method of transformer tap changing which comprises completing a series circuit through first and second windings of a transformer, changing taps on said second winding so as to vary the number of turns thereof in said circuit, completing said circuit through a different number of turns of said first winding and a third winding of said transformer in series while

excluding said second winding from said circuit, changing taps on said third winding so as to vary the number of turns thereof in said circuit, completing said circuit through said second winding and a still different number of turns of said first winding while excluding said third winding from said circuit, and again changing said taps on said second winding so as to vary the number of turns thereof in said circuit.

LOUIS F. BLUME. 10

CERTIFICATE OF CORRECTION.

Patent No. 2,200,979.

May 14, 1940.

LOUIS F. BLUME.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 60, claim 7, for the words "relation ship" read --relationship--; line 67, claim 8, for "friction" read --fraction--; line 74, same claim, before "winding" insert --main--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of June, A. D. 1940.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.