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2,342,084

TRANSFORMER TAP-CHANGING CIRCUIT

Filed March 14, 1940

Fig. 1.

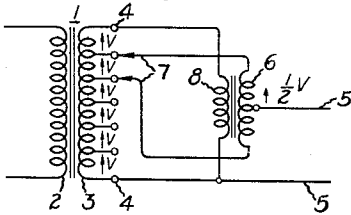


Fig. 2.

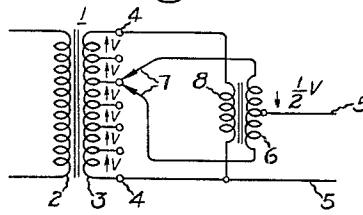


Fig. 3.

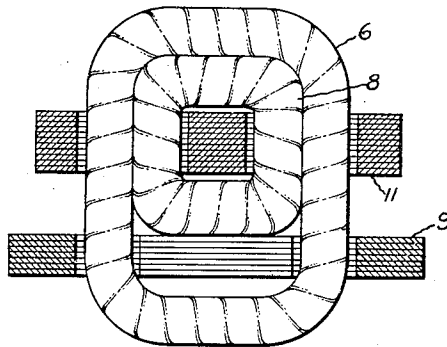


Fig. 4.

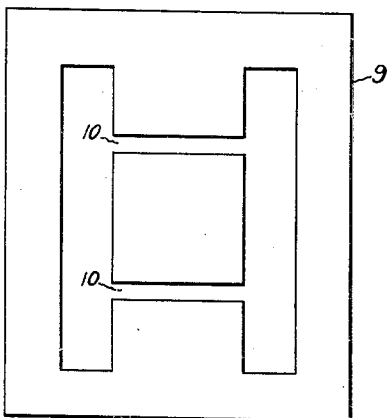
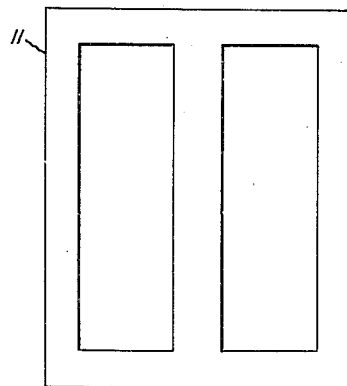


Fig. 5.



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TRANSFORMER TAP-CHANGING CIRCUIT

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6 Claims. (Cl. 171-119)

This invention relates to transformer tap-changing circuits and more particularly it is an improvement on Patent No. 2,188,173, granted January 23, 1940, on an application of Ralph B. Carson (now Reissue No. 21,854) and assigned to the assignee of the present application.

A common type of transformer tap-changing circuit which is used in load ratio control transformers and step voltage regulators employs a mid-tapped reactor in combination with tap-changing means which in one position thereof connects the reactor between any two adjacent transformer taps of a series of equally spaced taps and in another position thereof short circuits the reactor. The short circuiting position is often referred to as the full cycle position and the other position is often referred to as the half cycle or bridging position. As many regulating transformers of this type are adapted to be operated for equally long periods in either the full cycle or the half cycle position, the exciting current and its attendant losses of these transformers will vary from a relatively high value in the half cycle position to a relatively low value in the full cycle position, the difference in exciting current and losses in the two positions being caused, of course, by circulating current in the mid-tapped reactor which is caused to flow by the tap-to-tap voltage difference which is applied thereto in the half cycle position.

In the aforesaid Carson patent the exciting current and losses are equalized for the two positions of the tap changers by means of auxiliary windings on the main transformer which are connected in circuit respectively with the terminals of the reactor and which have voltages induced therein which are each equal to one-fourth of the tap-to-tap voltage. These one-fourth valued voltages act in the same direction in the reactor circuit and act in opposition to the tap-to-tap voltage. The result of this arrangement is that the same voltage is impressed across the reactor in both the full cycle and half cycle positions and this voltage is equal to one-half the tap-to-tap voltage. Thus, the maximum exciting current of the transformer is reduced, thus making it possible to reduce the rating and size of the reactor.

Experience with the Carson circuit has shown that it is not always convenient to place special auxiliary windings on the core of the main transformer. In some cases the number of turns required in such windings is so small as to make the winding impractical and in other cases of large or high voltage apparatus these windings

interfere with the best insulation structure and increase the difficulty of balancing the windings magnetically in order to minimize mechanical forces during short circuits.

I have solved the above-described problem which arises from the use of the Carson circuit by substituting for Carson's auxiliary windings on the main transformer an auxiliary transformer. Furthermore, in the preferred embodiment of my invention this auxiliary transformer and the reactor are combined into a unitary structure in which the single reactor winding also performs the function of Carson's two auxiliary windings.

An object of the invention is to provide a new and improved transformer tap-changing circuit.

Another object of the invention is to provide an improved tap-changing-under-load transformer which has the same exciting current in the full cycle and half cycle positions of its tap-changing means.

Another object of the invention is to provide a transformer tap-changing-under-load system with a novel mid-tapped reactor having the same exciting current in the full cycle and half cycle positions of the tap-changing switches.

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 Figs. 1 and 2 illustrate diagrammatically a preferred embodiment of my invention with the tap-changing means in the half cycle and full cycle positions respectively, Fig. 3 is a cross-sectional plan view of the combined mid-tapped reactor and exciting current equalizing auxiliary transformer, and Figs. 4 and 5 are side elevations of the reactor and transformer cores of the structure shown in Fig. 3.

Referring now to the drawing and more particularly to Figs. 1 and 2 there is shown therein a main transformer 1 provided with windings 2 and 3 which may be the primary and secondary windings or vice versa. Winding 3 is provided with a plurality of taps 4 whose voltages form an arithmetical progression, that is to say, the same voltage difference exists between adjacent taps. Winding 3 is connected in an external circuit 5 through a mid-tapped reactor 6 whose terminals are connected to tap changers 7. These tap changers may be operated manually or by any suitable and well-known mechanical means in such a manner than one of them is always connected to a tap, while the other one may be moved to an adjacent tap. During this motion

all of the current in the external circuit 5 is carried by one-half of the reactor so that the external circuit is never broken when its voltage is being regulated by the tap-changing operation. However, the tap changers normally make connection to either the same tap (full-cycle position) or to adjacent taps (half-cycle position) so that the load current normally flows through both halves of the reactor, thus neutralizing the impedance effect of the reactor with respect to the load current. It is only momentarily when one of the tap changers is in motion between adjacent taps that all the load current flows through one-half of the reactor. The half-cycle positions are preferably further characterized by their always applying the tap-to-tap voltage across the reactor with the same polarity.

In order to have the same circulating or exciting current in the reactor 6 in both the half cycle position of the tap changer 7 as shown in Fig. 1 and in the full cycle position as shown in Fig. 2 an auxiliary winding 8 is placed in inductive relation to the reactor winding 6. This winding may be energized in any suitable manner and as shown it is connected across the winding 3 of the main transformer. The ratio of turns of the windings 6 and 8 and the relative directions of these turns is such that winding 8 induces in winding 6 a voltage which is equal to one-half of the uniform tap voltage difference V and which is in such an instantaneous direction that it opposes the tap voltage difference V . Consequently, in the half cycle position the net or resultant voltage for exciting the reactor winding 6 is the difference between V and one-half V which, of course, is one-half V , while in the full cycle position the voltage one-half V which is induced in the reactor winding 6 is present for circulating current in the winding 6 or in other words, exciting this winding.

The load current in the external circuit 5 divides equally between the two halves of the reactor winding 6 in both the half cycle and full cycle positions of the tap changers and consequently this current has no magnetizing or exciting effect on the reactor.

Although the auxiliary winding 8 has been shown and described as inducing the one-half V value counter-voltage directly in the reactor winding 6, it will, of course, be obvious to those skilled in the art that this winding 8 could be in non-inductive relation with the winding 6 and could be provided with separate secondary windings connected respectively in series with the terminals of the winding 6, each of these secondary windings having induced therein a voltage equal to one-fourth V and in the same direction as the one-half V valued voltage which is induced directly in the winding 6.

I have found, however, that it is more economical to combine the reactor and auxiliary transformer into a unitary structure, the details of a preferred form of which are shown in Figs. 3, 4 and 5. In these figures the reactor winding 6 links the center leg of a three-legged core 9 which is provided with air gaps 10 for preventing saturation thereof. This core corresponds to the conventional reactor core. Winding 6 also links the center leg of a conventional three-legged transformer core 11. Winding 8 also links the center leg of the core 11 but it does not link the core 9. The core 9 provides a relatively low reluctance leakage path for the flux of the winding 6. This gives the winding 6 a high leakage

reactance so that it acts effectively as a reactor. The coupling between windings 6 and 8 is, however, relatively close by reason of the core 11 so that winding 8 readily induces in winding 6 the necessary one-half V valued voltage. Winding 8 therefore performs the dual function of a reactor and transformer secondary.

In Fig. 1 the external voltage impressed across the terminals of winding 6 is V . This is balanced by a pair of equal internal voltages, one of which is the voltage of mutual induction between windings 6 and 8, being induced in winding 6 by the flux in core 11, and the other of which is the voltage of self-induction of winding 6, being induced therein by the flux in core 9. In Fig. 2 the impressed voltage is zero. The one-half valued internal voltage of mutual induction is in that case balanced by the one-half V valued voltage of self-induction. The voltage of self-induction, or reactor voltage, of winding 6 is therefore the same in each case and consequently its exciting current is the same in each case except that their directions reverse. The one-half V valued arrows in Figs. 1 and 2 represent the self-induced reactor voltage in each case.

While there has been shown and described a particular embodiment 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. In combination, a transformer having a winding provided with a plurality of taps between electrically adjacent ones of which the same voltage difference exists, a pair of tap changers for selectively and sequentially making and breaking circuit connections to any of said taps, in such a manner that in alternate positions thereof they both make connection with a single tap, a reactor winding whose terminals are connected respectively to said tap changers, an external circuit for said transformer winding connects to the electrical midpoint of said reactor winding, and a third winding arranged in inductive relation to said reactor winding for inducing a permanent voltage in said reactor winding in opposition to said voltage difference and equal to one-half of said voltage difference.

2. In combination, a transformer having a winding provided with a plurality of taps whose voltages form an arithmetical progression, a reactor winding provided with a mid-tap, an external circuit for said transformer winding connected to said mid-tap, tap-changing means for connecting the terminals of said reactor winding to said taps in such a manner that in one position of said tap-changing means the tap-to-tap voltage difference which characterizes said arithmetical progression is applied across said reactor winding and in another position of said tap-changing means said reactor winding is short circuited, a pair of iron cores linking said reactor winding, one of said cores having an air gap and the other one being closed, an auxiliary winding linking the closed core but not the core with the air gap, and connections for energizing said auxiliary winding so that it induces in said reactor winding a voltage equal to one-half of said tap-to-tap voltage difference and in the opposite direction whereby the exciting current in said reactor winding is of the same magnitude in either

of said positions of said tap-changing means.

3. In a system for changing transformer taps under load, in combination, a main transformer winding provided with a plurality of taps having a uniform tap-to-tap voltage difference, a mid-tapped reactor, a pair of tap changers for connecting the terminals of said reactor to said taps in alternate full-cycle and half-cycle positions, said half-cycle positions being characterized by the application of the tap-to-tap voltage across said reactor always with the same polarity, and auxiliary transformer means comprising the reactor and an additional winding for inducing in said reactor in both said full-cycle and half-cycle positions a voltage equal to one-half said tap-to-tap voltage difference and in opposition thereto whereby the magnitude of the resultant voltage for circulating current in said reactor and tap changers is equal to one-half the tap-to-tap voltage difference in both the full-cycle and half-cycle positions.

4. In a transformer tap-changing system, a main winding provided with a plurality of taps, a pair of tap changers for selectively making connection to said taps, and a combined transformer-reactor comprising a pair of magnetic cores carrying a reactor-secondary winding whose terminals are connected respectively to said tap chang-

ers, said reactor-secondary winding having a mid-tap connected to a circuit for said main winding, and a primary winding carried by one of said cores to the exclusion of the other one.

5. In a transformer tap-changing-under-load system, a main transformer winding provided with a plurality of taps adjacent ones of which have the same voltage difference, a pair of tap changers for making connection to said taps alternately in full-cycle and half-cycle positions, an auxiliary transformer-reactor having a primary winding connected to be excited by said main transformer winding and a secondary-reactor winding whose terminals are connected to said tap changers respectively, a magnetic transformer core linking said primary and secondary windings, and a reactor core linking only said secondary winding.

6. In a transformer system, in combination, a three-legged closed magnetic core, a primary winding mounted on the center leg thereof, a secondary winding mounted on said center leg concentrically with and outside said primary winding, and a second magnetic core linking said secondary winding to the exclusion of said primary winding and provided with an air gap.

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