A single phase auto transformer.

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Description

The present invention relates to a single phase auto transformer, and relates particularly to an improvement for a single phase auto transformer having a tap winding and an exciting winding wound on an iron core side leg.

In view of an electric power transmission line stability and a protective relay specification, the smaller the transformer impedance variation due to the tap position change over, the better.

In one conventional single phase auto transformer having a small impedance variation due to tap position change over, a tap winding and an exciting winding thereof are wound on an iron core leg (side leg) other than one (main leg) on which a shunt winding and a series winding thereof are wound, and the exciting winding and the shunt winding are connected in parallel so that a change in current distribution flowing through the shunt winding and series winding caused by a change in tap position is prevented, In other words no change of magnetic flux density distribution at the iron core main leg portion is caused by the tap position change over, and a change in impedance at the iron core main leg portion is prevented even when a tap position is changed over. As a result, a change in impedance due to the tap position change over is limited to that at the side leg portion where the tap winding and the exciting winding are wound and a total impedance change of the transformer is rendered comparatively small.

The extent of the total impedance change of the conventional single phase auto transformer is limited to that of the ratio of voltage adjustment by the tap winding, i.e., when the voltage adjustment range of the single phase auto transformer is 10%, the total impedance of the transformer varies up to in an order of 10%.

An object of the present invention is to provide a single phase auto transformer having a small impedance variation when tap position of the tap winding thereof is changed over.

A single phase auto transformer of the present invention including a shunt winding and a series winding wound around a first iron core leg and a tap winding and an exciting winding wound around a second iron core leg is characterized in that said exciting winding is divided into first and second exciting winding units (I6a, I6b) connected in series, said first exciting winding unit (I6a) being arranged around said second iron core leg (12) inside said tap winding (17) and said second exciting winding unit (I6b) being arranged around said second iron core leg (12) outside said tap winding (17).

Number of turns of the first and second exciting winding units is preferably the same, however the number of turns of one exciting winding unit may be between 20-80% of the total required number of turns for the exciting winding of the single phase auto transformer depending upon the required winding structure of the tap winding.

One embodiment of the present invention will be described in the following with reference to the accompanying drawings.

Fig. 1 schematically shows one embodiment of a single phase auto transformer of the present invention.

Fig. 2(a) shows a winding arrangement at the side leg illustrated in Fig. 1.

Fig. 2(b) shows magnetic flux density curves for three tap positions at the side leg portion corresponding to the winding arrangement shown in Fig. 2(a) and a conventional winding arrangement.

Fig. 3 schematically shows transformer impedance curves of the present invention shown in Fig. 1 and the conventional single phase auto transformer with respect to three tap positions.

Fig. 1 is a diagram showing the arrangement of the windings of a single-phase auto transformer according to the embodiment of the present invention. In Fig. 1: reference numeral 10 designates an iron core having three legs; numeral 11 the main leg of the iron core 10; and numeral 12 the side leg of the iron core 10. Numerals 13, 14 and 15 designate a ternary winding, a shunt or common winding and a series winding, respectively, all of which are wound in the recited order on the main leg 11. Numerals 16a designates one of the two divided exciting windings, as will be referred to as a "first exciting winding". Numerals 16b designates the other of the two divided exciting windings, as will be referred to as a "second exciting winding". Numerals 17 designates a tap winding. These individual windings are wound on the side leg 12 such that the first exciting winding 16a is at the inner most side, the tap winding 17 at the intermediate and the second exciting winding 16b is at the outer most side. In other words, the tap winding 17 is sandwiched between the two divided exciting windings 16a and 16b.

The first exciting winding 16a and the second exciting winding 16b are connected in series with each other to provide a series circuit, with which is connected in parallel the shunt winding 14 to provide a parallel circuit, with which is connected the series winding 15.

In the auto transformer of the present embodiment the voltage of the secondary side, in that intermediate voltage side, is changed over. As indicated above, the series winding 15 and the shunt winding 14 are connected in series and one terminal of the tap winding 17 is drawn out as a secondary terminal u
and the other terminal thereof is connected to a common juncture of the series winding 15, the shunt
winding 14 and the second exciting winding unit 16b.

In the single-phase auto transformer thus constructed, the current distribution in the shunt winding 14
and the series winding 15 is never changed when the tap position of the tap winding 17 is changed over,
because the shunt winding 14 is connected in parallel with the series circuit of the exciting windings 16a and
16b, as a result, no change in magnetic flux density, thus no impedance variation at the main leg portion
occurs.

Moreover, since the exciting winding is divided into the first exciting winding 16a and the second
exciting winding 16b, between which is sandwiched the tap winding 17 to limit the impedance variation of the
single phase auto transformer because substantially the half of the exciting winding is arranged outside the
tap winding 17, the maximum magnetic flux density at the side leg portion is reduced to substantially the
half of the conventional single phase auto transformer having non-divided exciting winding.

As indicated previously, impedance change at the main leg portion does not occur so that the
transformer impedance variation is controlled by the impedance between the exciting winding and the tap
winding at the side leg portion.

Figs. 2(a) and 2(b) are a diagram showing the arrangement of the windings at the side leg 12, as shown
in Fig. 1, and a diagram showing the characteristics of the interlinking magnetic flux density in the
 corresponding positions. In Fig. 2(a), the same portions as those shown in Fig. 1 are designated at the
identical reference numerals. In Fig. 2(b), a curve 20 represents the magnetic flux density in the case of the
tap position at the highest voltage; a curve 22 represents the magnetic flux density in the case of the tape
position at the center; and a curve 21 represents the magnetic flux density in the case of the tap position at
the lowest voltage. Here:

\[ N_{E1} \]: Number of turns of the first exciting winding 16a;
\[ N_{E2} \]: Number of turns of the second exciting winding 16b;
\[ D_{E1} \]: Width (cm) of the first exciting winding 16a;
\[ D_{G1} \]: Size (cm) of the gap Gl between the first exciting winding 16a and the tap winding 17;
\[ D_{T} \]: Width (cm) of the tap winding 17;
\[ D_{G2} \]: Size (cm) of the gap G2 between the tap winding 17 and the second exciting winding 16b;
\[ D_{E2} \]: Width (cm) of the second exciting winding 16b;
\[ R_{E1} \]: Average radius (cm) of the first exciting winding 16a;
\[ R_{G1} \]: Average radius (cm) of the gap Gl; \[ R_{T} \]: Average radius (cm) of the tap winding 17;
\[ R_{G2} \]: Average radius (cm) of the gap G2;
\[ R_{E2} \]: Average radius (cm) of the second exciting winding 16b;
\[ I \]: Current (A) flowing through each of the exciting windings 16a and 16b;
\[ f \]: Frequency (Hz) of the current I;
\[ h \]: Height (cm) of each of the windings 16a, 16b and 17; and
\[ P \]: Reference capacity (VA) of the transformer.

Then, the % impedance voltage \( %V_{Z1} \) between the tap winding 17 and each of the exciting windings 16a and
16b of the present embodiment shown in Fig. 2(a) is generally expressed by the following equation (1):

\[
%V_{Z1} = \frac{7.9 f N_{E1}^2 \cdot I^2 \cdot \Delta_1}{P} \times 10^{-6} (%) \quad \cdots(1)
\]

Here, \( \Delta_1 \) is expressed by the following equation (2):
For comparison, % impedance voltage of the conventional single phase auto transformer having non-divided exciting winding, in that, schematically the second exciting winding unit is eliminated, is examined. In Fig. 2(b), a curve 23 represents the magnetic flux density when the tap position is at the highest voltage position, a curve 25 represents the magnetic flux density when the tap position at the center, and a curve 24 represents the magnetic flux density when the tap position at the lowest voltage position. Here:

\[ N_E: \text{Number of turns of the exciting winding;} \]
\[ D_E: \text{Width (cm) of the exciting winding;} \]
\[ D_G: \text{Size (cm) of the gap between the exciting winding and the tap winding;} \]
\[ D_T: \text{Width (cm) of the tap winding;} \]
\[ R_E: \text{Average radius (cm) of the exciting winding;} \]
\[ R_G: \text{Average radius (cm) of the gap between the two windings; and} \]
\[ R_T: \text{Average radius (cm) of the tap winding.} \]

Then, the % impedance voltage \( V_{Z2} \) between the tap winding and the exciting winding of the conventional single phase auto transformer is generally expressed by the following equation (3):

\[
%V_{Z2} = \frac{7.9 f N_E^2 \cdot I^2 \cdot \Delta_2}{p} \times 10^{-6} \text{ (\%)} \quad \ldots (3)
\]

Here, \( \Delta_2 \) is expressed by the following equation (4):

\[
\Delta_2 = \frac{D_E}{3} \cdot \frac{2\pi R_E}{h} + D_G \cdot \frac{2\pi R_G}{h} + \frac{D_T}{3} \cdot \frac{2\pi R_T}{h} \quad \ldots (4)
\]

When assuming that the specifications of the embodiment of the present invention and the conventional single phase auto transformer are the same, in that

\[ N_{E1} + N_{E2} = N_E. \]

Assuming further for example that,

\[ N_{E1} = N_{E2} = \frac{N_E}{2}. \]

and although \( \Delta_1 \) and \( \Delta_2 \) vary depending upon insulation distances between windings, however take for example,

\[ \Delta_1/\Delta_2 = 1.6. \]
Since \( f, I, \) and \( P \) are the same for the equations (I) and (3), the ratio of the two \% impedance voltages is expressed by the following equation (5):

\[
\frac{\%V_{Z1}}{\%V_{Z2}} = 0.4 \quad \text{...(5)}
\]

In other words, the impedance at the side leg portion is lowered to about 40\% in the structure of the present embodiment, in which the exciting winding is divided into two windings sandwiching the tap winding inbetween, than in the structure of the conventional one in which the exciting winding is not divided into two. Since the absolute impedance value at the side leg portion is thus reduced, the change in impedance, when the tap position is changed over is naturally reduced.

Fig. 3 shows transformer impedance variation of the present embodiment and the conventional single phase auto transformer with respect to tap positions. A curve 26 represents transformer impedance of the present embodiment and a curve 27 represents that of the conventional single phase auto transformer. In both curves, the minimum transformer impedance appears at the center tap position and the impedance gradually increases when the tap position moves away from the center position. As seen from Fig. 3, the transformer impedance variation of the present invention shown by the curve 26 is controlled smaller than that of the conventional single phase auto transformer shown by the curve 27.

Claims

1. A single phase auto transformer including first and second iron core legs (II, 12), a shunt winding (14) and a series winding (15) connected in series and wound around said first iron core leg (II) and a tap winding (17) and an exciting winding wound around said second iron core leg (12), said exciting winding being connected in parallel with said shunt winding (14) characterized in that said exciting winding is divided into first and second exciting winding units (16a, 16b) connected in series, said first exciting winding unit (16a) being arranged around said second iron core leg (12) inside said tap winding (17) and said second exciting winding unit (16b) being arranged around said second iron core leg (12) outside said tap winding (17).

2. The single phase auto transformer according to claim 1 wherein said tap winding (17) is connected in series with said shunt winding (14).

3. The single phase auto transformer according to claim 1 wherein said series winding (15) is arranged outside said shunt winding (14).

4. The single phase auto transformer according to claim 3 further comprising a ternary winding (13) wound around said first iron core leg (I) inside said shunt winding (14).

5. The single phase auto transformer according to claim 1 wherein the number of turns of said first exciting winding unit (16a) and said second exciting winding unit (16b) is substantially the same.

Revendications

1. Autotransformateur monophasé comprenant des première et seconde branches (11, 12) d'un noyau de fer, un enroulement shunt (14) et un enroulement sèrie (15) branchés en série et enroulés autour de ladite première branche (11) du noyau en fer, et un enroulement de prise (17) et un enroulement d'excitation, enroulés autour de ladite seconde branche (12) du noyau de fer, ledit enroulement d'excitation étant branché en parallèle avec ledit enroulement shunt (14), caractérisé en ce que ledit enroulement d'excitation est subdivisé en des première et seconde unités d'enroulement d'excitation (16a, 16b) branchées en série, ladite première unité d'enroulement d'excitation (16a) étant disposée autour de ladite seconde branche (12) du noyau de fer, à l'intérieur dudit enroulement de prise (17), et ladite seconde unité d'enroulement d'excitation (16b) étant disposée autour de ladite seconde branche (12) du noyau de fer, à l'extérieur dudit enroulement de prise (17)

2. Autotransformateur monophasé selon la revendication 1, dans lequel ledit enroulement de prise (17) est
branche en série avec ledit enroulement shunt (14).

3. Autotransformateur monophase selon la revendication 1, dans lequel ledit enroulement série (15) est disposé à l'extérieur dudit enroulement shunt (14).

4. Autotransformateur monophase selon la revendication 3, comportant en outre un enroulement ternaire (13) bobiné autour de ladite première branche (1) du noyau de fer, à l'intérieur dudit enroulement shunt (14).

5. Autotransformateur monophase selon la revendication 1, dans lequel les nombres des spires de ladite première unité d'enroulement d'excitation (16a) et de ladite seconde unité d'enroulement d'excitation (16b) sont sensiblement identiques.

**Patentansprüche**

1. Einphasen-Spartransformator mit einem ersten und einem Zweiten Eisenkernschenkel (11, 12), einer Nebenschlußwicklung (14) und einer Reihenschlußwicklung (15), die in Serie geschaltet und auf den ersten Eisenkernschenkel (11) aufgewickelt sind, sowie einer mit Abgriffen versehenen Wicklung (17) und einer Erregerwicklung, die auf den zweiten Eisenkernschenkel (12) aufgewickelt sind, wobei die Erregerwicklung parallel zu der Nebenschlußwicklung (14) geschaltet ist, dadurch gekennzeichnet, daß die Erregerwicklung in eine erste und eine zweite Erregerwicklungseinheit (16a, 16b) unterteilt ist, die in Serie liegen, wobei die erste Erregerwicklungseinheit (16a) auf dem zweiten Eisenkernschenkel (12) innerhalb der mit Abgriffen versehenen Wicklung (17) und die zweite Erregerwicklungseinheit (16b) auf dem zweiten Eisenkernschenkel (12) außerhalb der mit Anzapfungen versehenen Wicklung (17) angebracht ist.

2. Einphasen-Spartransformator nach Anspruch 1, wobei die mit Anzapfungen versehene Wicklung (17) mit der Nebenschlußwicklung (14) in Serie liegt.

3. Einphasen-Spartransformator nach Anspruch 1, wobei die Reihenschlußwicklung (15) außerhalb der Nebenschlußwicklung (14) angebracht ist.

4. Einphasen-Spartransformator nach Anspruch 3, ferner umfassend eine Ternärwicklung (13), die auf den ersten Eisenkernschenkel (1) innerhalb der Nebenschlußwicklung (14) aufgewickelt ist.

5. Einphasen-Spartransformator nach Anspruch 1, wobei die Windungszahlen der ersten und der zweiten Erregerwicklungseinheit (16a, 16b) im wesentlichen gleich sind.
FIG. 1

FIG. 3

Impedance

0
Lowest Center Highest

Tap Position