

POWER RECEIVING EQUIPMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001]

The present invention relates to three-phase power receiving equipment and particularly relates to three-phase power receiving equipment which can supply balanced voltages to loads stably even when the loads are unbalanced.

2. Description of the Background Art

[0002]

A three-phase AC voltage which is a high voltage not lower than 6 kV is distributed to any customer who consumes a large amount of power, such as a factory, a large-scale retail store, an office building or the like. On the other hand, a voltage is distributed via a single-phase three-wire type low-voltage distribution cable to any customer who consumes a small amount of power, such as a standard home, a small-scale retail store, a small-scale office building or the like.

[0003]

Fig. 4 is a diagram for explaining power receiving equipment in a single-phase three-wire type distribution system. The power receiving equipment receives a three-phase AC voltage which is a high voltage. The received three-phase AC voltage is transformed into a single-phase voltage of 200 V and

single-phase voltages of 100 V by a power receiving transformer disposed in the power receiving equipment, and supplied to a single-phase 200V load L3 or single-phase 100V loads L1 and L2.

[0004]

All the connected loads are single-phase loads in the single-phase three-wire type distribution system. In addition, those many single-phase loads are connected at random among lines of a single-phase three-wire type distribution cable. Further, the single-phase loads can be turned on/off at any time in accordance with customer's convenience. Thus, currents flowing in the lines of the single-phase three-wire type distribution cable are not always balanced. In the extreme case, only a load connected to one line and a neutral line may be operated while a load connected to the other line and the neutral line is out of service.

[0005]

Accordingly, there has been currently used a method of placing a transformer called a balancer in a tail end of a single-phase three-wire type distribution system to balance line currents.

[0006]

A balancer BL is a transformer with a turn ratio of 1 to 1 as shown in Fig. 4. The balancer BL is typically placed in a tail end of a single-phase three-wire type distribution

cable. When there is a difference between a current flowing in one line (outside line A) and a current flowing in the other line (outside line B) (that is, there is a difference in capacity between loads L1 and L2), the balancer provided thus supplies a compensating current i_o into the outside lines A and B to cancel the unbalance between the currents flowing in the outside lines A and B.

[0007]

When, for example, the current flowing in the outside line A is higher than the current flowing in the outside line B, a compensating current $2i_o$ flows from a neutral line C to the balancer, and a part i_o of the flowing current is supplied to the load L1 through a winding n_1 . On the other hand, the remaining part i_o of the flowing current flows into a power transformer T through a winding n_2 .

[0008]

When the balancer is provided thus, the outside lines A and B are coupled inductively through the balancer. Thus, even when there is an unbalance between a load connected to the outside line A and the neutral line C and a load connected to the outside line B and the neutral line C, or even when the neutral line C is disconnected on the power source side, the voltage between the outside line A and the neutral line C and the voltage between the outside line B and the neutral line C always operate in a balanced manner.

[0009]

In this manner, the balancer allows a compensating current to flow to balance the voltages on the both sides of the single-phase three-wire type distribution cable (the voltage between the outside line A and the neutral line and the voltage between the outside line B and the neutral line) and the currents flowing toward the power source through the outside lines.

[0010]

Fig. 5 is a diagram for explaining power receiving equipment with a three-phase AC transformer and a single-phase autotransformer (balancer) according to the background art.

[0011]

In Fig. 5, the reference numerals 51, 52 and 53 represent primary windings of the three-phase transformer respectively, which are delta-connected. The reference numerals 51', 52' and 53' represent secondary windings which are electromagnetically connected to the primary windings respectively, and which are star-connected.

[0012]

The reference signs R, S and T represent a-phase, b-phase and c-phase distribution lines respectively, through which three-phase power is supplied to a three-phase load L.

[0013]

The reference sign BL represents a balancer placed among the distribution lines R, S and T. The balancer BL has a first

winding 55 and a second winding 56 wound around an iron core 54. The first winding 55 and the second winding 56 are connected in series to generate magnetic fluxes whose directions coincide with each other. A midpoint tap n is derived from the series connection point.

[0014]

The balancer BL formed thus is connected between the a-phase distribution line R and the b-phase distribution line S.

[0015]

The reference numerals 58, 59 and 60 represent single-phase loads. Each single-phase load 58, 59, 60 is connected between the distribution line R or S and the neutral line C or between the distribution lines R and S.

[0016]

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[0017]

According to the aforementioned background art, balancers BL are connected respectively between output terminals a and b, between output terminals b and c and between the output terminals c and a in the three-phase transformer forming the high-voltage power receiving equipment, so that single-phase loads can be connected between the opposite terminals and the neutral point of each balancer BL while a three-phase load can be connected among the respective output

terminals of the three-phase transformer. In addition, the neutral point of the three-phase transformer can be grounded.

[0018]

When the neutral point of the three-phase transformer is grounded, the three-phase transformer can be miniaturized. Thus, the three-phase transformer can be formed into a light-weight and space-saving type power transformer. Further, it is possible to suppress increase of the voltage to ground.

[0019]

Although the primary windings 51, 52 and 53 of the three-phase transformer are delta-connected, the secondary windings 51', 52' and 53' electromagnetically connected to the primary windings are star-connected. Accordingly, a third harmonic component is generated in the secondary windings of the three-phase transformer. The generated third harmonic component affects the distribution lines R, S and T.

[0020]

When the neutral point of the secondary windings is not grounded, the potential in the neutral point fluctuates. When the neutral point is grounded, a third harmonic component current or the like flows in each distribution line with a return path to the ground, causing electromagnetic induction interference. It is therefore necessary to take measures against the electromagnetic induction interference.

SUMMARY OF THE INVENTION

[0021]

The present invention was developed in consideration of these problems. An object of the invention is to provide three-phase power receiving equipment which can suppress generation of noise due to a third harmonic component or the like, and which can use a light-weight and space-saving type power transformer.

[0022]

In order to attain the foregoing object, the invention uses the following means.

[0023]

The power receiving equipment includes a three-phase transformer having at least secondary windings delta-connected, and balancers each having first and second windings wound around an iron core. The first and second windings are connected in series to generate magnetic fluxes whose directions coincide with each other. The balancers are connected between output terminals of respective phases on a secondary winding side of the three-phase transformer respectively, while electric power is supplied to a three-phase load and single-phase loads. The three-phase load is connected to the respective phases on the secondary winding side of the three-phase transformer. The single-phase loads are connected in parallel to at least one of the first and second windings of each of the balancers.

[0024]

With the aforementioned configuration, the invention can form three-phase power receiving equipment which can suppress generation of noise due to a third harmonic component or the like, and which can use a light-weight and space-saving type power transformer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

Fig. 1 is a diagram for explaining a power feed system including power receiving equipment according to an embodiment of the invention;

Fig. 2 is a diagram for explaining the power receiving equipment according to the embodiment;

Fig. 3 is a view for explaining a single-phase three-wire type distribution system;

Fig. 4 is a diagram showing a balancer; and

Fig. 5 is a diagram for explaining power receiving equipment in the background art.

DETAILED DESCRIPTION OF THE INVENTION

[0026]

An embodiment of the invention will be described below with reference to the accompanying drawings. Fig. 1 is a diagram for explaining a power feed system including power receiving

equipment according to the embodiment.

[0027]

In Fig. 1, the reference numeral 1 represents a three-phase AC power generator; 2, a power transmitting transformer; 3, power receiving equipment including a power receiving transformer; and 4, a three-phase AC load.

[0028]

AC power generated by the three-phase AC power generator is stepped up by the power transmitting transformer and then supplied to the power receiving equipment including the power receiving transformer through a power grid. A three-phase AC voltage received by the power receiving equipment including the power receiving transformer is stepped down and then supplied to the three-phase load 4 or single-phase loads through three-phase distribution lines.

[0029]

Fig. 2 is a diagram for explaining the details of the power receiving equipment including the power receiving transformer.

[0030]

In Figs. 1 and 2, the reference numerals 11, 12 and 13 represent primary windings of the three-phase transformer (power receiving transformer), which are star-connected. The reference numerals 11', 12' and 13' represent secondary windings which are electromagnetically connected to the primary windings

respectively, and which are delta-connected.

[0031]

The reference signs R, S and T represent a-phase, b-phase and c-phase distribution lines respectively, through which three-phase power is supplied to the three-phase load 4.

[0032]

The reference signs BL1, BL2 and BL3 represent balancers placed among the distribution lines R, S and T.

[0033]

Each balancer BL1, BL2, BL3 has a first winding 22 and a second winding 23 wound around an iron core 21. The first winding 22 and the second winding 23 are connected in series to generate magnetic fluxes whose directions coincide with each other. A midpoint tap n is derived from the series connection point.

[0034]

The reference numerals 25 and 26 represent an outside line A and an outside line B of a single-phase three-wire type distribution cable using the secondary winding 11' of the power receiving transformer as a power source. Single-phase loads (100V loads) 27 and 28 and a single-phase load (200V load) 29 are connected between the outside lines A and B and a neutral line C connected to the midpoint tap n respectively.

[0035]

As shown in Fig. 1, the primary windings 11, 12 and 13

of the power receiving transformer forming the power receiving equipment are star-connected, while the secondary windings 11', 12' and 13' electromagnetically connected to the star-connected primary windings are delta-connected. Accordingly, even when a third harmonic component is generated in each of the secondary windings of the three-phase transformer forming the power receiving transformer due to magnetic saturation or the like in the iron core forming the power receiving transformer, the harmonic component circulates in the delta-connected secondary windings 11', 12' and 13'. Thus, the problem of induction interference caused by the third harmonic component can be substantially ignored.

[0036]

Fig. 3 is a view for explaining another example of a balancer. As shown in Fig. 3, the balancer is constituted by first to fourth windings n_1 to n_4 . The first winding n_1 and the second winding n_2 are wound around one of legs of an iron core F shaped with a hollow square, while the third winding n_3 and the fourth winding n_4 are wound around the other leg of the iron core shaped with the hollow square. The third winding n_3 , the first winding n_1 , the second winding n_2 and the fourth winding n_4 are connected in series to generate magnetic fluxes whose directions coincide with each other. Balancers formed thus are connected between the output terminals of the respective phases of the delta-connected secondary windings of the

aforementioned three-phase transformer. In addition, the output terminals of the delta-connected secondary windings of the three-phase transformer and connection terminals between the first windings and the second windings of the balancers are used as feed terminals of distribution lines.

[0037]

Each balancer BL1, BL2, BL3 is a transformer whose turn ratio is 1 to 1, and which is connected in parallel to the secondary winding 11', 12', 13'.

[0038]

Due to the balancer provided in parallel to the secondary winding forming each phase, a compensating current i_o can be supplied from a neutral point 24 to each single-phase load 27, 28 even if the single-phase loads 27 and 28 are unbalanced. It is therefore possible to cancel the unbalance between the currents flowing in the outside lines A and B.

[0039]

When, for example, the current flowing into the load 27 is higher than the current flowing into the load 28, the compensating current i_o flows into the balancer from the neutral point $\underline{n}$, and flows out through the windings 22 and 23. In this manner, when the balancer is provided, the loads 27 and 28 are inductively connected through the windings 22 and 23. Even when there is an unbalance between the load connected between the outside line A and the neutral line C and the load connected

between the outside line B and the neutral line C, and even when the neutral line C is not connected to the power source side (the midpoint of the secondary winding 11' of the transformer), the balancer always operates to balance the voltage between the outside line A and the neutral line C and the voltage between the outside line B and the neutral line C. Similarly, even when the neutral line C of the balancer BL2, BL3 is not connected to the midpoint of the secondary winding 12', 13', the balancer always operates to balance the voltage between the outside line A and the neutral line C and the voltage between the outside line B and the neutral line C.

[0040]

When the balancer is provided thus, the voltages applied to the single-phase loads 27 and 28 can be always balanced.

[0041]

Here, assume that i_a , i_b and i_c designate a current flowing through the balancers BL1 and BL3, a current flowing through the balancers BL1 and BL2 and a current flowing through the balancers BL2 and BL3 respectively, L designates self-inductance of each winding of the balancers, and M designates mutual inductance. The following expressions are established.

$$2j\omega L \cdot i_a + z_i(2i_a - i_b - i_c) = j\omega M(i_b + i_c) \quad \dots(1)$$

$$2j\omega L \cdot i_b + z_i(2i_b - i_c - i_a) = j\omega M(i_c + i_a) \quad \dots(2)$$

$$2j\omega L \cdot i_c + z_i(2i_c - i_a - i_b) = j\omega M(i_a + i_b) \quad \dots(3)$$

Here, due to $L \cong M$, the following expressions are obtained from the expressions (1), (2) and (3).

$$(2i_a - i_b - i_c)(j\omega L + z_i) = 0 \quad \dots(4)$$

$$(2i_b - i_c - i_a)(j\omega L + z_i) = 0 \quad \dots(5)$$

$$(2i_c - i_a - i_b)(j\omega L + z_i) = 0 \quad \dots(6)$$

In addition, the following expression is obtained from the expressions (4), (5) and (6).

$$i_a = i_b = i_c \quad \dots(7)$$

[0042]

In addition, when z_i is selected to establish $j\omega L + z_i = 0$, the windings of each balancer can be grounded with low impedance so that noise can be suppressed effectively. In addition, potential V_N in the neutral point is expressed by:

$$V_N = (E_{ab} + E_{bc} + E_{ca}) / 2 = 0$$

Thus, the neutral point $\underline{n}$ can be grounded.

[0043]

That is, the neutral point $\underline{n}$ of each balancer can be grounded through a grounding impedance Z_i . Thus, even if noise invades the distribution cable or the like, the noise can be released to the ground potential so that the noise can be suppressed.

[0044]

Thus, any equipment connected to the single-phase three-wire type distribution cable can be protected from noise invading the equipment from the outside.

[0045]

As described above, according to the invention, the power receiving equipment includes a three-phase transformer having at least delta-connected secondary windings and balancers each having first and second windings wound around an iron core. The first winding and the second winding are connected in series to generate magnetic fluxes whose directions coincide with each other. The balancers are connected between output terminals of respective phases on a secondary winding side of the three-phase transformer respectively, while electric power is supplied to a three-phase load and single-phase loads. The three-phase load is connected to the respective phases on the secondary winding side of the three-phase transformer. The single-phase loads are connected in parallel to at least one of the first and second windings of each of the balancers.

[0046]

Accordingly, balanced power source voltages can be always supplied to the single-phase loads even if there is an unbalance between the single-phase loads.

[0047]

In addition, the neutral point 24 of each balancer can be grounded through the grounding impedances Z_i . Accordingly, even if noise due to a third harmonic component or the like invades the distribution cable or the like, the noise can be released to the ground potential so that the noise can be

suppressed.

What is claimed is:

1. Power receiving equipment comprising:

a three-phase transformer in which at least secondary windings are delta-connected; and

a plurality of balancers each of which has a first winding and a second winding wound around an iron core, the first winding and the second winding being connected in series to generate magnetic fluxes whose directions coincide with each other; wherein:

the balancers are connected between output terminals of respective phases on a secondary winding side of the three-phase transformer respectively, while electric power is supplied to a three-phase load and single-phase loads, the three-phase load being connected to the respective phases on the secondary winding side of the three-phase transformer, the single-phase loads being connected in parallel to at least one of the first and second windings of each of the balancers.

2. Power receiving equipment comprising:

a three-phase transformer in which at least secondary windings are delta-connected; and

a plurality of balancers each of which has a first winding and a second winding wound around an iron core, the first winding and the second winding being connected in series to generate magnetic fluxes whose directions coincide with each other; wherein:

the balancers are connected between output terminals of respective phases on a secondary winding side of the three-phase transformer respectively, and a series connection point between the first winding and the second winding of each of the balancers is grounded through an impedance, while electric power is supplied to a three-phase load and single-phase loads, the three-phase load being connected to the respective phases on the secondary winding side of the three-phase transformer, the single-phase loads being connected in parallel to at least one of the first and second windings of each of the balancers.

3. Power receiving equipment according to Claim 2, wherein:
the impedance has a value to resonate with self-inductance of one of coils of the balancer.

4. Power receiving equipment according to Claim 2, wherein:
each of the balancers includes first to fourth windings, the first and second winding being wound around one of legs of an iron core shaped with a hollow square, the third and fourth windings being wound around the other leg of the iron core shaped with the hollow square, the third winding, the first winding, the second winding and the fourth winding being connected in series to generate magnetic fluxes whose directions coincide with each other; and

the balancers are connected between the output terminals of the respective phases of the delta-connected secondary windings of the three-phase transformer, the output terminals

of the delta-connected secondary windings of the three-phase transformer and connection terminals between the first windings and the second windings of the balancers are used as feed terminals of distribution lines.