A paper presented at the 20th Annual Convention of the American Institute of Electrical Engineers, Niagara Falls, N. Y., July 1st, 1903.

Y OR △ CONNECTION OF TRANSFORMERS.

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The two alternative methods, Y or △, of connecting transformers to a three-phase system, come up for discussion with every three-phase installation. A general statement of the advantages and disadvantages of both connections, as they appear to the writer, is given here with the hope that those engineers who have had most experience with power transmission will contribute their views on the subject.

TRANSFORMERS.

Assuming that three transformers are to be used for a three-phase power transmission, and that the potential of the line is settled, each of the transformers, if connected in Y, must be wound for $\frac{1}{\sqrt{3}}$ or about 58 per cent. of the line potential, and for the full line current. If connected in △, each transformer must be wound for the line potential and for 58 per cent. of the line current. The number of turns in the transformer winding for Y connection is, therefore, but 58 per cent. of that required for △ connection and the cross section of the conductors must be correspondingly greater. The greater number of turns in the winding, together with the insulation between turns necessitates a larger and more expensive coil for △ connection. The larger coil calls for a longer magnetic circuit and consequently a larger and heavier transformer throughout. This is of no importance when the potential of the coil is low or when the transformer is large and the current high. In fact, in transformers in which the current is heavy it is usual to divide the conductors into several multiple circuits for ease of handling and to avoid eddy current losses that occur when the cross section of the conductor is too large. A few turns more or less in the winding under such conditions is, therefore, immaterial.

In transformers of small capacity wound for high potential, the cost and weight are both considerably in favor of the Y connection of the high potential coils.

Where it is desired to secure the smallest transformers that can be wound for any given potential, the minimum size of wire that can be employed in the windings of the high potential coils and give sufficient mechanical strength, is the limiting feature. A transformer practicable for Y connection may be smaller therefore than can be commercially considered for △ connection.

The Y connection requires the use of three transformers, and if anything goes wrong with one of them the whole bank is disabled. With the △ connection, one of the transformers can

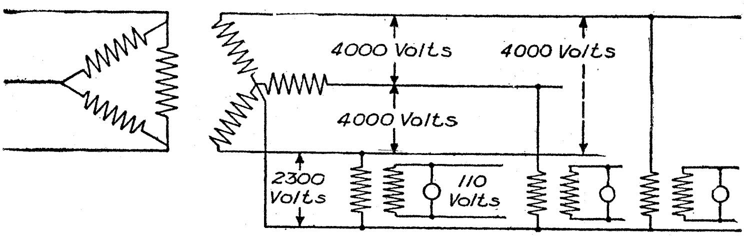

Fig. I Step Down Transformer For 4000 Volt Y Distribution

be cut out and the other two still deliver three-phase power up to their full capacity; that is, two-thirds of the entire bank.

Combined three-phase transformers are generally of small size and on that account are preferably Y-connected on the high potential side.

GROUNDING THE NEUTRAL.

If the common connection of transformers joined in Y is grounded, the potential between windings and the core is limited to 58 per cent. of that of the line, and the insulation between the windings and core might be proportionally reduced. The same argument applies to the transmission circuit and would allow the size of the line insulators to be reduced.

The saving that can be made in insulating transformers by grounding the neutral is not great with large transformers, but is important on small ones, as the space taken up by the insulation for any given potential is relatively greater in a small transformer. Under normal conditions, the potential between any conductor of a three-phase transmission circuit and the ground is 58 per cent. of the line potential, with either Y or △ connection, but the neutral may drift so as to increase the potential with an ungrounded system. If one branch is partly or completely grounded, the potential between the other two branches and the ground is, of course, increased and may be the full line potential. With a grounded neutral Y system, a ground is a short circuit of the transformers on the grounded branch and the transmission becomes inoperative.

From the point of view of safety to life and prevention of fires this is a desirable condition, especially if the low tension distribution is also grounded. If the high tension circuit makes contact with the ground or low potential system, it can be immediately cut out by fuses or automatic circuit breakers.

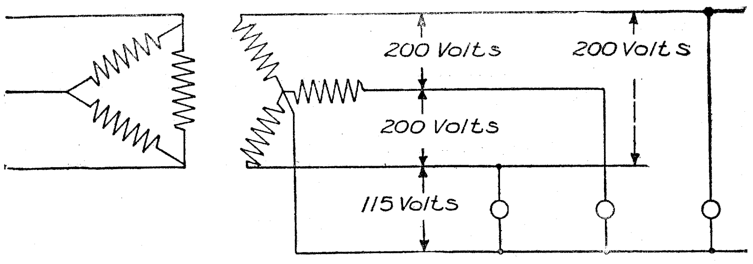

Fig. 2 Step Down Transformer For 200 Volt Y Distribution

The difficulty is that a power transmission with grounded neutral is likely to be frequently shut down by temporary grounds, such as would be caused by a tree blowing against one of the wires. Even if the circuit is not opened, the drop in the pressure due to the sudden " short " on the line will cause synchronous apparatus to fall out of step. Under the same conditions a system without a grounded neutral would give uninterrupted service.

Unstable Neutral.

If two transformers are connected in series, there is no certainty that they will divide the potential equally between them. A system in which all the electrical apparatus is connected in Y has somewhat the same characteristics. The neutral may drift out of its proper place and there will be unequal potentials between it and the three conductors of the circuit, due to unequal loading and differences in the transformers or transmission circuits. Such unbalancing would cause unequal heating of the transformers and if a four-wire three-phase system of distribution were employed, would seriously interfere with the regulation of the voltage. In transformers, therefore, have Y secondaries, it is desirable that the primary should be △ connected. Two systems in common use with which △ primary windings should be used, are shown in Figs. 1 and 2.

Rise of Potential.

The high potential windings of transformers are necessarily of high reactance, and if left in series with a circuit of large capacity, as shown in Figs. 3, 4, 5 and 6, the leading charging current flowing over the reactance may set up extraordinarily high pressures. Figs. 3 and 4 represent Y connected banks of three transformers, each connected so as to cause such a rise of potential. In Fig. 3 the primary of one trasformer is excited by a generator, the primary of the other two transformers being

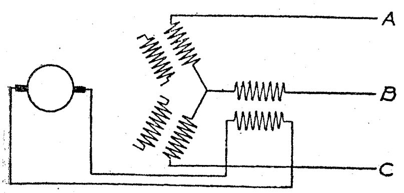

Fig. 3

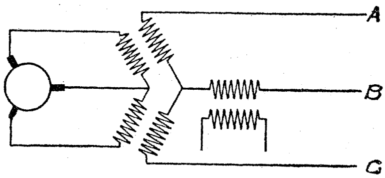

Fig. 4

open-circuited. In Fig, 4 the primary of one transformer is open circuited, the other two being connected to the generator. Figs. 5 and 6 show T connected banks of two transformers, which might be used to transform from either two-phase or three-phase to three-phase or vice versa, and are similar in action to Fig. 3. If in any one of Figs. 3, 4, 5 or 6 the secondaries are connected to a long distance transmission circuit, a pressure of many times the normal potential will be set up between A and B, and between B and C, that between A and C not being affected.

It is theoretically possible for a potential 100 times that for which a transformer is wound, to be caused by opening the primary switches of one or more of the transformers of a bank connected in Y before the secondary switches are used. Of course, actually, the current jumps across the insulation at some point in the system before there can be any such increase in pressure. If there are a number of banks of transformers in parallel, this phenomena cannot occur except when all but one bank are disconnected. This source of trouble could be obviated by employing oil switches on the high potential side which disconnect the line before the low tension switches are used, or by triple pole switches on the primary which open all three branches of the bank of transformers at once.

The selection of Y or △ connection of transformers for long distance transmissions should only be determined after a careful consideration of the conditions in each case.

There is little choice between Y or △ without a grounded neutral.

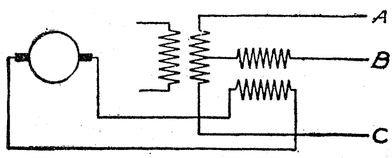

Fig. 5

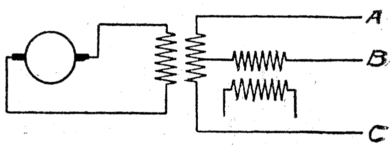

Fig. 6

In small installations, the cheaper cost of transformers for Y with a grounded neutral will be a determining factor. Larger plants will be guided by the greater importance of giving uninterrupted service and will not employ a grounded neutral unless demanded on the score of safety.

Where the amount of power is great and the system extensive, △ connection will be generally preferred on account of its avoiding the possibility of rises of potential from any cause. Many plants can have advantageously a mixed system with both Y and △ transformers, each installation of transformers being considered by itself.