SORGEL COMMUNICATOR

SORGEL TRANSFORMERS · SQUARE D COMPANY

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Unusual Problems with WYE Connected, Three Phase Power Transformers

Three phase wye-wye connected *core type* transformers can present a hazard unless proper precautions are taken. For the benefit of those who may be involved in such a situation, we have prepared a detailed analysis of what could occur.

BACKGROUND

A large percentage of our three phase power transformer production is of the core type construction. There are at least four reasons why this is so.

1. Only 3 core legs require stacking in place of 4 or 5 in the shell type. This reduces the labor content of the finished product thus providing a more economical transformer.
2. Core steel does not completely encircle the outer coils thus providing more space for cooling ducts and free air flow.
3. The core is not adjacent to the outer sections of the end coils thus removing heat generating sources which improves cooling action.
4. The core type does not require as much floor space; a more critical dimension than vertical height.

Of these, No. 1 and No. 4 are of the greatest import to the user. Reference to Fig. 1 will help to clarify the foregoing statements.

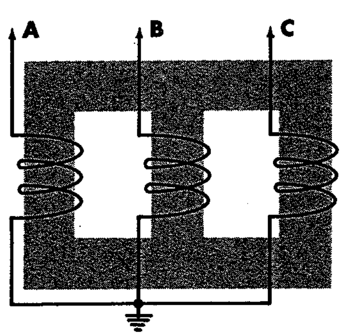

FIG. 1a CORE TYPE

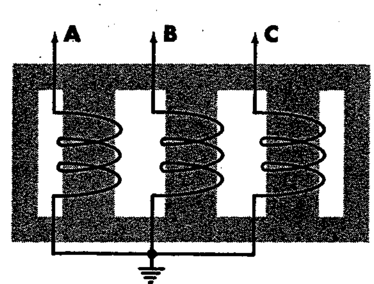

FIG. 1b SHELL TYPE

While most of the units we produce specify a delta primary, there are still a substantial number of users who order wye primaries. It seems appropriate, therefore, to alert our readers to *unusual* conditions which can convert the normal function of the unit from that of an efficient transformer to an equally efficient, yet destructive, induction heater!

MAGNETIC FIELD

In a rotating generator it is an accepted fact that as a conductor passes through a magnetic field, current is caused to flow in the conductor. Because a transformer is a static device its conductors are stationary but the magnetic lines of force (flux) are in motion also causing current to flow in the windings. The magnetic steel which is formed into a transformer core provides a much easier path for flux to flow through than is true of air. In a well designed power transformer only a small share of the total flux fringes out into the surrounding air, where it is known as leakage flux.

Under *normal* conditions of balanced transformer loading, leakage flux poses no problem, because almost all of the flux is contained within the core structure where we desire it to remain. If a condition *can* exist, wherein a substantial percentage in the flux of the core leg is *prevented* from traveling within its normal path, then it must, of necessity, find an alternate path outside the core and coil structure. Because large transformers include rugged structural steel bases, clamping angles, tie rods and enclosure panels, these components become an effective undesirable path for the leakage flux.

ALMOST A DISASTER!

With over 50 years of transformer experience, it is evident we were tuned in to the problems of the industry as disturbing reports were recorded of peculiar, unexplained, happenings that occurred throughout the nation with wye connected transformers produced by a number of manufacturers. One of the more interesting experiences that involved our own transformers more than 20 years ago took place in a Midwestern city.

The superintendent of a public building observed flickering lights. He proceeded immediately to the transformer vault and detected severe vibration noise within the transformer itself, so he pulled the main switch. Other lights in the vicinity served by a second vault, acted similarly. He rushed to that vault, opened the doors, and found the transformer starting to burn at the top of one coil. Again he pulled a switch and extinguished the flames with a conveniently available fire extinguisher.

The natural assumption was that by coincidence two transformers had failed internally, simultaneously. A desperation phone call to Milwaukee and a quick flight by the Chief Engineer of Sorgel, brought him to the distant city in a matter of hours. What was uncovered is explained in the following paragraph.

A large three phase motor had failed causing the blowing of one line fuse in the main feeder serving the building. With four wire, grounded neutral primary transformer connections, the two remaining phases and the neutral continued to energize the transformers. The unobserved motor failure created a ground in parallel with the primary winding in the isolated phase, causing severe winding circulating currents in addition to the induction heating phenomenon in the structural members of the transformers. Isolation of the defective motor, fuse replacement to restore full four wire wye service, and determination that the windings were not damaged permitted the superintendent to re-energize the transformers, proving that they were still operable. What would have been a long outage was averted by prompt action to de-energize the transformers before irreparable damage occurred, and the fact that the mica insulation in all of our transformers was able to withstand fire damage of short duration. Twenty years later, the same transformers, without repair, are still functioning. The customer is still a staunch supporter of Sorgel products!

Many technical reference books, university text books and articles are available to the interested reader who may desire to delve into a detailed study of circuit phenomena that can occur under adverse conditions. Our function is not to duplicate those writings in the Communicator, but to try to present the facts in nontechnical language that will communicate the probabilities of operating problems.

WYE-WYE BANKS

Assume we have a three phase, core type transformer (either dry or liquid filled), connected as in Fig. 2a. Fig. 2b shows only the external leakage flux pattern in a core type transformer for the unusual conditions to be explained later.

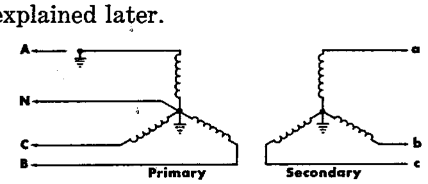

FIG. 2a

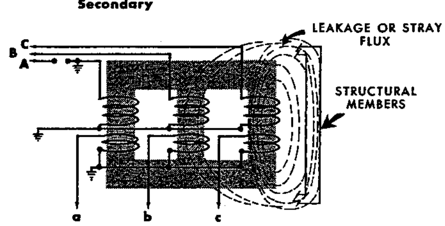

FIG. 2b

In a typical *distribution* system, with a primary neutral grounded as in 2a, the stage is set for a related problem similar to the practical problem described in the previous paragraphs. Assume the main feed is overhead and during a storm a tree limb breaks Line A, and simultaneously grounds it on the load side of the break. Obviously no line current can flow in the shorted A phase primary winding now isolated from its power source. On a substantial distribution system, back-up protective equipment will not operate because the shorted winding does not create currents large enough in phases B or C to blow line fuses or to trip breakers.

However, the other two phases continue to create magnetic flux in their respective core legs but because of the shorted A phase winding, flux from the other two core legs is effectively blocked from entering the A core leg. Because the flux generated in B & C legs *must* return to the particular core leg in which it originated it is forced to find an exterior path such as indicated by the dotted lines, either through air or adjacent metal parts. The greatest percentage of these will find the path of lowest reluctance (least magnetic resistance) which will be the closest cabinet panels and structural steel. That such a condition is of no small moment is evidenced by actual field experiences wherein the structural members and panels are raised to an extreme heat condition actually causing them to weld together. We are aware of similar experiences in oil filled transformers in which tank heating was sufficient to cause severe paint blistering.

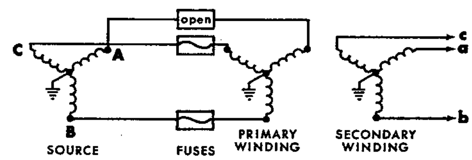

FIG. 3

Another condition that can occur in plants or buildings also involve the wye-wye core type transformer when the primary and secondary winding neutrals are grounded. If the fuse in primary line A illustrated in Fig. 3, blows for any reason, the secondary will continue to supply 3 phase power to its connected load. With no primary current in phase A, the remaining two phases B & C, will endeavor to supply the load at some reduced effectiveness. The net result is increased current demand in primary phases B & C, which if permitted to continue, will overheat these two windings to ultimate destruction. It is not likely the fuses in B or C will blow before damage results.

These two cases alone, among a variety of others that could be cited, clarifies why our recommendation is to counsel against a grounded wye primary connection unless the user will install sensitive protective equipment to clear all three phases when unusual vagaries of fate place a transformer into difficulty. A delta primary makes life so much easier.

CONCLUSION

For those readers interested in pursuing this subject further, the following references may be of interest. These more complex writings go into considerable analysis of third harmonics in zero phase sequence currents and flux behavior for a wide variety of transformer connections and fault conditions.

REFERENCES: Principles of Electrical Engineering Series, Magnetic Circuits and Transformers EE Staff MIT, the Technology Press, John Wiley & Sons, Inc., Chapters 10, 12, 13, 24 & 26 / Transformer Engineering by Blume, John Wiley & Sons, Inc., Chapter 7 / Electrical Engineer's Handbook by Pender & Del Mar, Section 3, Pages 39 & 40 / Electric Utility Engineering Reference Book, Volume III, Distribution Systems, Westinghouse Electric Corp., Chapter 6