TRANSFORMER - Causes of failures

The fault that most frequently occur in practice may be classified broadly as follows, although to a large extent the different kinds often react upon one another :

A. Failures in the magnetic circuit, i.e., in the cores yokes and adjacent clamping structure.
B. Failures in the electrical circuit, i.e., on the coils and minor insulation and terminal gear.
C. Failures in the dielectric circuit i.e., in the pil and major insulation.
D. Structural failures.

REMARKS

A. Failures in the magnetic circuit.

(1) Cases have occurred from time to time in connection with core type transformers of a breakdown of the insulation round the bolts inserted through the cores and yokes for the purpose of clamping the laminations together. This type of fault has the effect of causing local short circuits in the laminations themselves, which produce intense) local eddy currents. The path formed by the bolts and the thick outer clamping plates is one of low impedance, and the amount of heat generated by failures of this type is sometimes sufficient to distort the whole core to a very considerable extent. The heat generated may also char the coil insulation and cause a short circuit between turns of the adjacent winding.

(2) Failure may also occur of the insulation between laminations and of the insulation between the yokes and yoke-clamping plates.

(3) Unless very special precautions are taken to lock effectively the core clamping bolts and the bolts tying together the core structure, vibration will be set up which will tend to weaken the core insulation and produce failures similar to those outlined above.

(4) High saturation of the magnetic circuit often results in heavy magnetising current rushes occurring when switching a transformer into circuit or no load. While this current rush generally dies down rapidly, large electromagnetic forces are generated while the heavy current lasts and the windings are thereby strained. The phenomenon becomes more severe the nearer the transformer is located to the generating sources, and repeated switching it may ultimately cause disrupture of the windings.

B. Failures in the electric circuit.

(1) A short circuit between adjacent turns of a coil - usually of the high pressure winding - may be caused by the presence of sharp edges on the copper conductors if the transformer vibrates when on load, or if the windings are subjected to repeated electromagnetic shocks, through short circuit of switching in, these sharp edges will cut through the insulation and allow adjacent turns to make metallic contact.

(2) A short circuit between turns may result from the dislodging of one or more turns of a coil caused by a heavy external short circuit across the winding Breakdown may not occur immediately the turns are displaced, but should the transformer vibrate while on load due to looseness of core bolts, or should it receive repeated heavy electromagnetic shocks, abrasion of the insulation between adjacent dislodged turns will most likely take place, so producing a breakdown.

(3) Transformers for use on heavy powered systems are now usually fitted with adjustable coil supports for the purpose of taking up any shrinkage of the insulation which may occur under service conditions. Unless this hand adjustment of the coil supports is performed very carefully by an experienced workman, so as not to place too great a mechanical pressure on the windings, some of the conductors may become dislodged and a short circuit between turns may occur.

(4) Short circuits between turns are almost bound to occur sooner or later should moisture penetrate the fabric insulation of the coils. Breakdown from this cause is rendered more imminent still if the coils have been insufficiently impregnated, i.e., if the varnish has not thoroughly .penetrated to the innermost layers of the coils.

(5) Drying out a transformer on site may be undertaken by an engineer not fully conversant with the operation, and the process may be unduly shortened. If normal electrical pressure or a testing pressure is switched on while the insulation resistance of the windings is still low, the insulation between adjacent turns is very liable to fall at some point or other on account of the presence of moisture vapour.

(6) Badly soldered joints between coils may overheat on load and local carbonisation of the oil may occur. The head generated. at the joint will probably be transmitted to a certain contiguous length of conductor of each coil, and this may partially carbonise the insulation round the conductors and eventually result in a short circuit between turns. Such Joints may eventually come apart and produce an open circuit in the winding concerned.

(7) In very high pressure transformers dielectric losses in the insulation may lead to excessive heating and ultimate failure of the latter.

(8) Coil conductors may be displaced violently on the occurrence of an external short circuit, as the result of internal unbalanced electromagnetic conditions. With concentrically wound primary and secondary coils (as in the circular core type of transformer) the horizontal axes may not coincide, and therefore a vertical force acting upon the coils is introduced in addition to the usual radial one.

(9) Short circuits between turns, breakdown of windings to earth, and puncture of insulators may take place due to the following transient phenomenon :

concentration of pressure on the terminal end coils when switching in or when lightning discharges reach the transformer. Owing to the change of surgs impedance at the transition point between transformer, and line, the phenomenon of reflected and transmitted pressure and current waves occurs, which may produces high pressure rises in the transformer windings. While the end coils bear the burnt of the shock, the remainder of the windings is not immune against breakdown, as high pressures may still penetrate any part of the windings.

(10) Sustained heavy overloads produce high temperatures throughout the transformer. The coil insulation becomes brittle, and in time probably flakes off the conductors in places, so producing short circuits between turns. The oil deposits sludge both on the tank bottom and on the coils and core structure, the deposit exerts a blanketing effect on the coils and core, so the excessive heating becomes cumulative in effect. Narrow oil ducts also intensify the heating. Transformers with a high' ratio of copper loss to iron loss are less able to withstand overload, and are therefore more liable to fail on account of the troubles arising from this phase of operation.

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C. Failure in the dielectric circuit.

(1) Moisture entering the oil as a result of the so-called `breathing' action greatly reduces its dielectric strength, so that breakdown from coils or terminal leads to tank or core structure may take place.

(2) Deterioration of the oil may occur as the result of prolonged overloading of the transformer, and the action in materially assisted be the presence of bare copper and load. Excessive oil temperature produces the formation of sludge, water, and acids.

(3) Earth shields placed between primary and secondary windings have been responsible for numerous breakdown. Their presence produces a concentration of dielectric stress at their edges, which tends to strain the near-by insulation, while a breakdown at one point from the high pressure windings to the shield has often resulted in almost completely destroying the high pressure and low pressure windings on the limb concerned.

(4) Narrow oil ducts are a serious menace to the serviceable life of a transformer. Adequate cooling can not be obtained, the coil insulation because brittle in time, and a fault between turns naturally follows.

D. Structural failures.

(1) Transformers operating in parallel should preferably possess the same turns ratio, the same percentage impendances and the same ratios of resistance to reactance pressure drops. If any of these factors are different, one transformer at least may be overloaded, and may consequently burn out.

(2) In water-cooled transformers the cooling tubes are liable to become clogged due to deposits of lime or other matter from the water supply. If the tubes are not thoroughly cleaned out periodically the water flow becomes lessened, and the transformer will attain a temperature higher than the maximum permissible with the usual subsequent results.

(3) In water-cooled transformers there is a further risk of introducing moisture to the oil by condensation. When the transformer is on load, the cooling water and the pipe surrounding it are naturally at a very much lower temperature than the oil and gases at the top of the tank. The effect of this is to cause any moisture which may be present in these gases to be deposited on the cooling tube at the point where it enters the tank. This moisture would subsequently drip into the oil, and unless means were adopted for rendering the tank airtight, the process would be continuous. The risk of failure due to this phenomenon may, however, be minimised by lagging the cooling tube from the point where it enters the tank to a point below the oil level with some material which is not effected by oil and *which* is a non-conductor of heat.