CHAPTER FIVE

INSTALLATION, TESTING AND MAINTENANCE OF POWER DISTRIBUTION TRANSFORMER

BY

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5.1 INTRODUCTION

Transformers are a live wire for all power transmission systems. Simply put, they are used for the purpose of voltage changing. Many types exists viz. power transformers (for transmission and distribution of electrical energy); auto-transformers (for starting motors); instrument transformer (for circuit measurement) and test transformers (for producing high-test voltages). Transformers can be of the single phase or three-phase types. Irrespective of the type of power distribution transformer, the basic components are reasonably the same. They are a static type of machine designed for transformation of one alternating current system into another with a different voltage and current characteristic.

Any system put in place must be SAFE, RELIABLE (CONTINUOUS) and EFFECTIVE, thus transformers must be installed, tested and properly maintained in order to achieve the desired objective(s) in the power system. To install is to place or fix something in position for use and the act of doing this is referred to as INSTALLATION. Thus, when a transformer is put in place ready for use anywhere within the power system, it is said to have been installed through an installation process.

Before installation and after, it is very necessary to ascertain the state of the transformer. This is only possible through testing, that is, subjecting the transformer to certain conditions that will show its qualities.

In order that the installed transformer perform reliably, safe and effective, it is very necessary to keep it in good condition. One way to do this is through MAINTENANCE. To maintain is to keep up; retain or continue and the art of keeping up or retaining in good condition is referred to as maintenance.

5.1.1 BASIC COMPONENTS OF POWER DISTRIBUTION TRANSFORMERS

The transformers consist basically of a magnetic circuit (CORE) on which the WINDINGS are placed. It also comprises a number of constituent parts and elements designed mainly to facilitate the transformer use and maintenance.

These include:

(a) Various insulators (solid and liquid) for insulation/isolation of current carrying parts;

(b) Bushings; and

(c) Leads for connecting the windings to the transmission lines;

(d) Switch gear (tap changer or tap switch) for the transformer voltage adjustment;

(e) Tanks to contain the transformer oil and other accessories;

(f) Cooling tubes and Radiators to enhance transformer cooling;

(g) Protective gear which operates when a fault arises in the transformer viz Bucholz Relay.

Other components include: Oil conservator (to house excess oil resulting from expansion and also to supplement the oil level); the Dehydrator and the Thermosiphon filter (to absorb the moisture carried by the air that enters the transformer thereby protecting the oil against moisture and catches particles in the incoming air thereby acting as a filter). Thermisphon filters are installed on large transformers 2.5MVA and above allowing them to be operated for a very long time without having to remove the transformer from service for oil purification and regeneration thus maintaining the desired purity and dielectric strength; the oil gauge (which indicates the oil level when the transformer is being filled with oil after repair and also in service).

The basis of this brief on the basic components of transformers is to prepare a standard point for maintenance. All transformers need not have all the components described above. This is a function of the transformer rating (size) and duty. These components are sources of failure that will become evident during tests and therefore requiring maintenance (replacement or repairs).

5.1.2 TRANSFORMER SUBSTATIONS

Substations abound in the power system. The prime objective is to effectively and efficiently transmit and distribute electrical energy to the various and numerous customers connected to the system. The stations are usually located such that voltage drops as well as losses are minimized. The substations can be grouped as follows:

(a) The Grid Substations (also injection substations) at 132/33KV or 132/11KV,

(b) The Primary Substations at 33/11KV; and

(c) Secondary Substations at 11/0.415/0.24KV.

The capacities of the various substations are within the following ranges:

(i) 10 – 30MVA and 20 – 90MVA for the grid;

(ii) 5 – 20MVA and 5 – 30MVA for the primary and,

(iii) 100 – 2000KVA and 500 – 7500KVA for the secondary substation respectively for the various consumers listed.

Substations can be of the indoor or outdoor types. Irrespective of the types the following components are present: high voltage equipment, step-down transformers, consumers low voltage equipment, meters and protection equipment (circuit breakers, fuses). The location of the substation is such that it is near the load centre in order to reduce the cable length and hence, power loss and voltage drop.

All stations should be of fireproof construction, well ventilated and dry. Cables are contained in earthenware pipes within the substation, or in concrete ducts in the floor cast in situ (for the indoor types).

In general, transformer installation can be grouped as follows:

(i) Pole mounted units;

(ii) Outdoor units and

(iii) Indoor units.

Underground substations also exist.

5.1.3 TRANSFORMER TESTS

Tests are the principal means of detecting troubles and defects in electric equipment (transformers, motors, generators, etc.) and of checking the quality of repair. Each test has certain objective(s), techniques and requirements. The tests can be broadly categorized as pre-installation/repair and post-installation/repair test respectively. The objective of the pre-test is to determine the state of the transformer and/or the scope and nature of the repair/maintenance work done or to be done, and also, to supply the performance data with which the post installation/repair/maintenance results are to be compared with. The essence of the post-test is to check the workmanship to make sure the transformer is free from defects that might upset its normal operation, to see that its performance complies with its data sheet values and applicable specifications and standards.

5.1.3.1 APPLICATION TEST STANDARDS AND SPECIFICATIONS

These use the following terms and concepts:

(i) Power Frequency Test Voltage

(ii) Rectified Test Voltage

(iii) Normally Insulated Electric Equipment

(iv) Low Insulation Level-electric Equipment

(v) An Unqualified Quantity.

Transformers are tested in accordance with a program, which includes the detection of likely defects and a check on the performance characteristics for compliance with relevant standards or specifications.

In Summary, transformer tests can either be

(i) Routine tests: All transformers are subjected to these.

(ii) Type tests: These are carried out on the first unit only of a new design.

Also, we can talk of preliminary and final test respectively. The former are tests carried out before transformer is assembled in its tank in order to ensure that any faults detected are rectified and include the following: Core Insulation, Ratio, Polarity and Resistance test respectively. The final tests are carried out complete with all external components and fittings which are likely to affect the performance of the transformer and generally include the following:

(i) Ratio and Polarity tests;

(ii) Surge-voltage withstand test;

(iii) Separate-source-voltage withstand test;

(iv) Induced-over-voltage withstand test and internal discharge test;

(v) Resistance of windings (DC resistance test);

(vi) No-load loss and no-load current test (open circuit test);

(vii) Noise test (humming);

(viii) Zero sequence impedance test;

(ix) Temperature rise test and

(x) Insulation resistance test.

All the tests are routine tests except (ii) and (x) which are type tests and
(iii) and (ix) which are special tests.

The acceptance test sequence is as follows:

(a) Electric strength of transformer oil

(b) Winding insulation resistance

(c) Electric strength of insulation with applied voltage

(d) Electric strength of insulation with induced voltage

(e) Open-circuit conditions.

There are yet other tests, referred to as proof tests. These are test applied to individual parts and units of a transformer in the process of manufacture and assembly. The purpose of these tests is to prevent faulty parts and units from being installed in the transformer and check those parts and units, which cannot be tested in the finished transformers. These are primarily the windings, core and switches.

The following tests constitute those in the post repair category:

(1) Oil test;

(2) Transformation ratio/angular (vector) displacement group,

(3) DC resistance of windings,

(4) Open – circuit and short – circuit current and losses,

(5) Insulation resistance of the windings,

(6) Applied high tension, power frequency test of the major insulation for dielectric strength,

(7) Induced-voltage test of the turn insulation for dielectric strength.

It is not possible that at any point in time, all of these tests MUST be performed. However, various authorities – power supply authorities and manufacturers make specific demand and requirement for transformers before being certified fit to be hooked up to the entire system. By NEPA standards, it is necessary and required that the following tests be carried out on transformers:

(a) Insulation resistance test,

(b) Ratio test

(c) Excitation test

(d) Oil test

5.1.3.2 **TRANSFORMER TEST PROCEDURES**

(A) **TRANSFORMER OIL TEST**

The oil is tested for dielectric strength and dielectric loss. (Note: the oil acts as an insulant and a coolant). The Dielectric strength test is carried out in a break-down high voltage tester. Acceptable values are 25KV for transformers up to 15KV and 30KV for transformers above 15KV to 35KV.

The oil might also be subjected to chemical analysis in order to determine its acid number, flash point of its vapour, the reaction of a water extraction, the suspended carbon content and the mechanical impurity content (See Fig. 5.1).

(B) **INSULATION RESISTANCE TEST**

This test is performed to ascertain that the windings are free from defects, that is, they are CLEAN and well DRIED. This warrants the winding's immunity to damage that may occur during electric strength test. In all, the value obtained assesses the degree of dryness and the likelihood of use without additional drying. The value obtained depends on the dryness and temperature of the winding. The value is measured using a megger between each winding and earth and between the windings at different voltages.

For transformers in sizes up to 35KV, an insulation resistance value of 300MΩ at 20°C is satisfactory for transformers in sizes up to 6.3MVA inclusive, and for transformers of sizes 10MVA and higher, a value of 600MΩ at 20°C is satisfactory.

In general, 1000MΩ at a test voltage of 100V is satisfactory (Say, M.G.) and NEPA accepts any value between 200MΩ and infinity.

(C) D.C. RESISTANCE TEST

This is performed to ascertain whether any unnoticed fault due to broken parallel conductors, poor soldered (brazed) joints at the tap changer exist. These defects increase the contact resistance at the joints and within defective sections resulting in increased values of d.c. resistance. The variations in resistance between the phases and the various steps of voltage control should not exceed 2%. The test is performed using an avometer. The test ensures that there are no faulty joints or breaks in multi-stranded conductors.

(D) THE OPEN-CIRCUIT AND SHORT-CIRCUIT CURRENT AND LOSS TEST

The open-circuit test (or core loss and magnetizing current test) is carried out in order to detect defects in the core of the transformer which may lead to an increase in the open-circuit (magnetizing current and the associated losses so that the overall efficiency of the transformer is reduced or the transformer is over heated. The test is also used to check the transformation ratio, this should not differ from the specified value by more than +5%. The value for the magnetizing current must not, be more than 2-3% of the specified load current value and the core loss must be very small.

The purpose of the short circuit test is to determine the short circuit losses and the impedance voltage. Defects mentioned under the D.C resistance test can be detected by a short circuit test. This test is also known as the load loss or impedance test. Fig. 5.3 shows the schematic test diagram and the short circuit voltage across the transformer is known as the impedance voltage (V_{sc}).

(E) THE RATIO AND PHASE INTER CONNECTION TEST

Fig 5.4 shows the circuit Diagram used for measuring the transformation ratio, used to check the phase inter connections and the connection of taps to the tap changer (switch).

The phase inter connections are checked to make sure that the windings have been interconnected correctly (POLARITY) and that the angular (phase) displacement is as it should be. (See fig. 5.4/A11).

(E) The Applied High-Tension, Power Frequency (50HZ) Test of The Major Insulation For Dielectric Strength.

Note:

(1) The test is performed with the applied voltage first across the L.V windings, and then to the high voltage windings.

(2) For oil-immersed transformer, the major insulation test voltage is 25KV for transformer in sizes up to 6KV; 35KV for transformers in sizes up to 10KV; and 85KV for transformers in sizes up to 35KV. (The insulation between the L.V winding and the core, and that between it and the H.V winding is major).

(3) By this test external insulation strength between the winding and earth is ascertained dismissing the possibility of any short circuit (high current or low voltage).

See fig. 5.5 for the test circuit.

THE INDUCED HIGH-VOLTAGE TEST OF THE TURN INSULATION

This test aims at ascertaining the internal insulation strength viz. interturn and inter coil to be sure that no short circuit can result because of poor insulation between them that is, it proves that the insulation strength between the turns and between other parts of the transformer operating at different potentials is okay.

The test voltage is 115% of the rated value for bolted cores, and 130% of the rated value for bootless (or banded) cores.

The transformer is taken to have passed the test, if no current in rushes, discharges and other symptoms of defects are observed during 1 minute of the test period.

Other tests that can be performed include the temperature rise test (oil temperature not to exceed (55°C to 65°C), transformer tank fitness, voltage adjustment arrangement (including the mechanism controlled by relays which must also be tested).

5.1.4 INSTALLATION OF POWER-DISTRIBUTION TRANSFORMERS

Different types of substation exist in the entire power system namely injection substation (at the grid level 132/33KV or 132/11KV to feed various zones and districts). Primary substations (33/11KV to feed major industrial, commercial and medium sized consumers); secondary substations (11/0.415/0.240KV to feed small industrial, small commercial and domestic consumers). They vary in sizes and complexity and also in size, complexity and installation techniques.

Depending on the size of the installation, one or more supply feeder cables will be brought into one or more substations viz. Fir injection to various primary substations to various secondary substation and then to consumers. The substation is built to house the step-up transformers and/or step down transformers, the consumers low voltage equipment, meters, protection equipment (circuit breakers and fuses)and feeder pillar.

The substation should be of fire proof construction, well ventilated and dry. Adequate space should be allowed for moving equipment about and provision should be made to limit the spread of fire in the event of escape of burning oil. Also, the substation must be prevented from intruders and should be kept very clean and tidy:

Substation/transformers are installed outdoors, indoors and some transformers are mounted on H-type poles. However, one must properly site the substation in order to minimize cable runs, power losses and voltage drops. The entire process requires that the following actions be taken in general:

i. Survey
ii. Construction
iii. Testing, and
iv. Commissioning

Basically a substation needs a building, or fence and plinth(s) plus high voltage control equipment (in most cases), a transformer or transformers, and a low voltage distribution board of either the indoor or street feeder pillar type (comprising incoming withdrawable links, phase and neutral busbars and high breaking capacity fuses (for up to eight outgoing distributor cable ways). Resettable maximum-demand indicators are often fitted to enable a check to be check to be kept of transformer load.

The only productive component in a substation is the transformer. All other items, including building and civil works are to the detriment of economy and the associated low voltage (L.V) network.

It is worthy to note at this point that injection substation make provision for offices and/or residential quarters for staff and space for some key operation personnels.

5.1.4.1 SURVEY

The aim is to locate an appropriated or best site for the substation and assess the civil works to be carried out as well as all the materials/other accessories required.

The primary and grid substation sties require a large space which can be very costly and individual design problem adopted to save space and contain transformer noise. For space economy without compromising standard, substations occupy the following land areas:

i Primary substation : about $836m^2$

ii Secondary substation : " $15m^2$

iii Grid substation : " 1672 to $2508cm^2$ or 2 to 3 time that of primary substation.

For a grid/injection substation, a compact installation is possible at the extra cost of more civil works, plants elaborate fire and safety precautions.

Some common instruments for use includes pencil, paper, cutlass, pegs, tape for measurement, razor set. All these will assist from the mapping of the area to the construction stage.

5.1.4.2 <u>CONSTRUCTION & INSTALLATION</u>

This includes both civil and electrical works ranging from the foundation level for the substation building (indoor) and the plinths (for outdoor substation), the fencing (outdoor) and other electrical gadgets.

The located site is pegged and the civil/building works commence getting an appropriate base ready for the transformer and other accessories to be put in place. For a typical secondary substation with between 100-500KVA transformer, the size of the plinth is about 1.52m x 1.22m x 1.22 (5'x4'x4') and the fence size is about 4.57m x 3.05m (15'x10'x10') covering a gross area of about 150 square feet ($13.94m^2$). The figures (A18/A19,6,7,8) show the various outlay. It should be noted that no construction can commence without the appropriate drawings/plan/sketch/schematic for all the electrical and civil works.

The other figures (A18 & A10) show typical out door and indoor substations at the primary and secondary levels respectively. (See Appendixes).

For indoor substations, provisions are made to limit the spread of fire in the event of the escape of burning oil. This is achieved by placing oil-filled equipment above a pit filled with graded chippings. This tends to absorbed lacking oil. The floor is sloped away from switch gear (the gradient being not less than 1 meter in 100m) towards the sump so that tin the event of water getting into the substation, it will run away from switch gear. Windows should be located high up the walls and glass should be unbreakable. DOORS should be of solid construction and kept locked, KEYS being retained by a responsible person and the supply authority. Emergency doors must be fitted with crash barriers.

*The list of materials for the construction of a typical distribution substation (300KVA) is given in sections 1.4.5.

5.1.4.3 **Testing**: The purpose for tests has already been dealt with. A list of the most relevant ones (post installation test) are here enumerated.

i. Insulation resistance of the lines (HT) and their associated auxiliaries such as insulators and lightning arrestors,

ii. Insulation resistance tests for the H.T and L.T cables and their associated auxiliaries such as feeder pillar, H.T fuse holders,

iii. Insulation resistance test of the transformer windings HT/LT, HT/E and LT/E (200-MΩ okay),

iv. Ratio tests of the transformer,

v. Excitation test through the secondary windings with the primary open,

vi. Dielectric strength test for the oil,

vii. Testing the earth resistance of the substation including the transformer neutral, channel iron, cables, feeder pillar, transformer body, lightning arrestors. (1-10Ohms okay). These tests must be separately done and all metal works should be bounded if possible.

5.1.4.4 **COMMISIONING**

This is done after all the necessary and required tests have been satisfactorily carried out by switching on the transformer on no load. The output voltage is monitored and the necessary tap changing effected. The transformer is allowed for at least twenty-four hours in this state before it is loaded, synchronized with the entire power system a process known as 'SOAKING'.

5.1.4.5 **Materials Required For the Erection of A 300KVA Distribution Substation.**

These include:

1. 2 Nos. 10.36m or 34' wooden or concrete H – type pole;

2. 1 complete se (3 Nos) of J & P 'D' fuse;

3. 1 set of 11KV lightning arrestor;

4. 100m, 70mm^2 base hard drawn copper;

5. 20 Nos. 6' galvanized earth rod;

6. 1 No. 300KVA, 11/0.415KVA transformers;

7. 1 No. 4 ways feeder pillar;

8. 15 Nos. bimetal line lap;

9. 2 lengths channel iron 5" x 3" x 21'

10. 15m, $70mm^2$ 3-core, PVC, 11KV U/G cable;

11. 1 Raychem kit, 3 core, outdoor termination $(50-95)mm^2$;

12. 1 Raychem kit, 3 core, indoor termination $(50-95)mm^2$;

13. 1 Raychem kit mounting bracket complete with insulators;

14. 24, Nos. $70mm^2$ cable socket;

15. 8 Nos., $300mm^2$ cable socket;

16. 1 No. Everite pipe;

17. 24m, $300mm^2$ single core PVC U/G cable;

18. 3 tins fluxite soldering paste;

19. 4 sticks plumbers metal 40/60 alloy;

20. 95 sticks tin man's soldier 60/40 alloy;

21. 4 litres kerosene oil;

22. 4 litres electro clean solvent;

23. 1 roll kaleris tape;

24. 5 rolls Lassoric tape;

25. 45m, $70mm^2$ 4 core PVC U/G cable (for 3 outgoing units ate least with each outgoer cable being approximately 15m);

26. Sufficient cement/gravel/chain link;

Note: If the O/H mains has not been strung to substation location, the following materials will be included to the list:

27. Bolt & nuts, (9Nos 5/8x2"; 12Nos 5/8x7"; 12nos 5/8x9"; 12Nos 5/8x11".

28. 6 Nos. 11KV pin insulator;

29. 6 Nos. 11 KV spindle;

30. 6 Nos. pilot spindle;

31. 6 Nos. 11KV (Disc) strain insulator

32. 6 Nos. Adaptor socket clevis (pilkington type);

33. 6 Nos. Adaptor clevis ball;

34. 6 Nos. Galvanised steel iron, six-bolt clamp;

35. 2 Nos. 11KV stay insulator;

36. 2 Nos. 11KV stay rod 7/8x8";

37. 30m, 7/8 S.W.G. stay wire.

5.1.5 MAINTENANCE OF POWER-DISTRIBUTION TRANSFORMERS

Maintenance, in general is a process which involves REPAIR, REPLACEMTENT, AND RENEWAL in order to ensure that systems/artifacts are in good working condition at all times.

The OBJECTIVE of maintenance is to attain a condition where the system or artifact ALWAYS function as if they were new. No known methods exist for preventing normal were and tear of components, modules and systems/subsystems.

The maintenance process INVOLVES the minimization, containment and CORRECTION of the wear and tear.

Different types of maintenance can be embarked upon to cater for both natural and artificial conditions and include the following:

i. Preventive

ii. Schedule and

iii. Breakdown, maintenance respectively.

Similarly repairs can be categorized as minor and major repairs respectively.

Maintenance is related to the cost and complexity of the equipment viz the maintenance of pole mounted transformers and those in generation and transmission. Since each maintenance operation has its own risk to introducing a cause of failure, care MUST be taken not to over-maintain the equipment. The periods adopted for maintenance usually takes into consideration: ENVIRONMENTAL factors, LOADING and MODE of USE. In most cases, the procedure is to INSPECT the possible cause of FAILURE and only if necessary, to carry out further work. There must also be a system of reporting defects found in order to maintain the confidence in the scheme.

5.1.5.1 TRANSFORMERS FAULTS

In order to maintain, repair or replace any equipment and associated component of an equipment, it is paramount to know the basic component of the equipment and also, the possible faults that can occur on an equipment. The basic components of the transformer include the core, the windings, the tank, the tap changer, the dielectric, (oil, bushing, paper, wood) and other accessories such as indicators (oil level, temperature), breathers, conservators, protection equipment (relays) and fans. Failure can occur due to a malfunction from any of the listed items. Generally, the causes of faults may be due to insulation deterioration, faulty manufacture or maintenance or excess applied voltage. The following is a general classification of transformer faults.

(1) Phase-to-phase faults on the HT connections or windings;

(2) Earth faults on HT windings or connections;

(3) Phase-to-phase faults on LT windings or connections;

(4) Earth-faults on LT windings or connections;

(5) Phase-to-phase faults on tap-change gear;

(6) Earth faults on tap-change gear;

(7) Interturn faults in main tank;

(8) Interturn faults in tap-change compartment;

(9) Core faults;

(10) Low oil;

(11) Over load and

(12) Tap-change mechanism.

5.1.5.2 TIPS ON TRANSFORMER MAINTENANCE

The following is a guide to enhance transformer maintenance practice all bothering on safety, reliability and cost effectiveness.

(1) Transformer should be inspected thoroughly as soon as they are received from the manufacturer or supplier;

(2) Distribution transformers should never be energized unless the oil is at the proper level;

(3) Transformers should be handled with care, avoiding server jarring that might damage the internal structure;

(4) Transformers should always be inspected by the crew before installation, that is the bushings, access plates and other fittings should be inspected and thoroughly tightened before the transformer is placed in operation;

(5) When replenishing oil care must be taken so that;

(i) moisture does not enter the transformer
(ii) nothing falls into the tank

(6) Transformers should never be moved or lifted by the bushings or other attachments but with the lifting lugs provided for this purpose;

(7) When a transformer is mounted on a pole, care should be taken to see that the transformer is in a vertical position and securely fastened so that a severe impact against the pole will not jar it loose;

(8) When performing maintenance inspections, all bushings, connections, protective devices, gaskets, the paint finish on the tank, and all other exterior fixtures should be inspected for evidence of rust, corrosion or over-heating. The oil level should be checked, and the condition of the oil tested;

(9) If an inspection cover is removed from a transformer for inspection, it should be replaced. If the gasket is not in perfect condition. It should be replaced;

(10) When working with any transformer, the connections on both the high and low sides should be opened, to avoid danger from feedback voltage.

5.1.5.3 THE PURPOSE OF TRANSFORMER MAINTENANCE

A few basic procedures avert costly transformer failures and interruption of service after they have been properly installed due to periodical inspection and maintenance. If these procedures are neglected over the years a transformer might fail without any warning causing expensive repairs or replacement and loss of production. This is the essence of transformer main tenance.

5.1.5.4 MECHANICS (WAYS) OF PROPER TRANSFORMER MAINTENANCE

This basically consist of

(1) keeping all parts clean and protected from rust, dirt, and corrosion

(2) testing the winding insulation and the insulating cooling liquid

(3) inspecting and testing the protective and indicating devices

(4) inspecting the transformer internally

(5) inspecting the auxiliary equipment such as fans, coolers, lighting arrestors and grounds.

5.1.5.5 RULES GOVERNING TRANSFORMER OPERATION

Although a transformer and its associated equipment does not have as many moving parts as most electrical equipment, the same basic rules still apply. These basic fundamental rules are:

(1) Current carrying components must operate in a moisture-free insulating liquid or area,

(2) The installation must be kept clean from dirt, rust or corrosion,

(3) All moving parts must be kept well lubricated

(4) All enclosures containing insulating and cooling liquids as well as weather proof enclosures that protect the equipment from the weather must be kept tight.

5.1.5.6 INSPECTION AND MAINTENANCE OF TRANSFORMERS

The frequency of inspection and maintenance of transformers and their associated equipment varies but basically depends upon their SIZE, TYPE and USE. Large power transformers normally require more frequent inspection and maintenance than small lighting and distribution transformers. This is due mainly to the fact that they are costly to replace, they serve electrical equipment critical for plant production, they have more associated equipment such as cooling fans, forced oil pumps or protective alarms that must be properly maintained to insure a trouble-free installation etc. Operation personnel should make a schedule for inspection and maintenance keep a log book and closely follow the schedule. The record kept should list information relative to the installation showing the transformer specifications/characteristics part history, repairs and tests made and spare parts.

The following includes most of the equipment that requires periodic inspection and maintenance and if a schedule is made and followed closely by the plant personnel and operators continuos service and trouble-free installation is assured: load and voltage; liquid level; temperature (for oil, air and water); pressure vacuum gauge (for sealed tank transformers and gas-oil-sealed preservation systems; fans pumps and their controls; dehydrating breathers; pressure-relief devices; insulating liquid, core and coils. The adjoining tables explain and illustrate inspection and maintenance actions to be taken.

.1.5.7 ADAPTIVE MAINTENANCE OF POWER-DISTRIBUTION TRANSFORMERS

This is based on 'copy creativity' and 're-inventing the wheel' theories. It is enhanced by proper knowledge of the entire power system/transformer sub-components. The object is to source materials locally and improve the reliability of the transformer. It also reduces the bulk weight of the transformer. The theory of adaptive maintenance is also possible only when the roles played by the sub-components and their characteristic factors complementing such roles are obvious to the maintenance staff. Research has looked into the possibility of using wooden bushings and vegetable oils as alternatives to porcelain bushings and transformers. This is due to the cost savings of the former and their ready availability as well as the fact that their source of origin is a renewable one. Shock absorption capability of wooden bushings vis-à-vis their porcelain counterpart is another major in consideration favour of wooden bushing. Bushings are meant to serve as external connector from the terminal leads with the transformer to the exterior. They should isolate these live conductors from the body. Similarly, transformer oil acts as a coolant and insulant carrying away heat from the core and windings/associating insulators and also strengthening inter coil insulation. These two: wooden bushing and coconut oil have been used on a 10KVA, 50Hz, 11/041 5 kV distribution transformer prototype and the results, were very encouraging in comparison with a standard identical control prototype. In mind was that indoor substation and transformers with concealed bushing cabinet exist, thus weather hazards are reasonably taken care of in the use of wooden busing replicas. For vegetable oils, their chemical stability is yet to be fully ascertained. However, both models have not been used under sustained simulated/practical load conditions over a reasonable length of time. The figures show the wooden busing prototypes and the Table show a comparative test results for busing (wooden/porcelain) and oil (transformer oil and vegetable oil).

5.1.6 CONCLUSION/RECOMMENDATION

Maintenance culture is very necessary for any equipment designed, produced, installed and commissioned to render specific services. This must become part of our technological awareness if we want to operate safe, reliable and efficient systems. Aspect such as rewinding, heat treatment, cannibalized varnish impregnation were not dealt with in detail but constitute vital aspects of maintenance of transformers.

It is recommended that power supply authorities look in the direction of adaptive technologies as a way to enhance reliability, continuity, efficiency and cost effectiveness in their short and long term plans and management for the systems. They should also encourage training/retraining of staff (technical) with new theories and development in their areas of specialization (maintenance of installed plants and equipment.

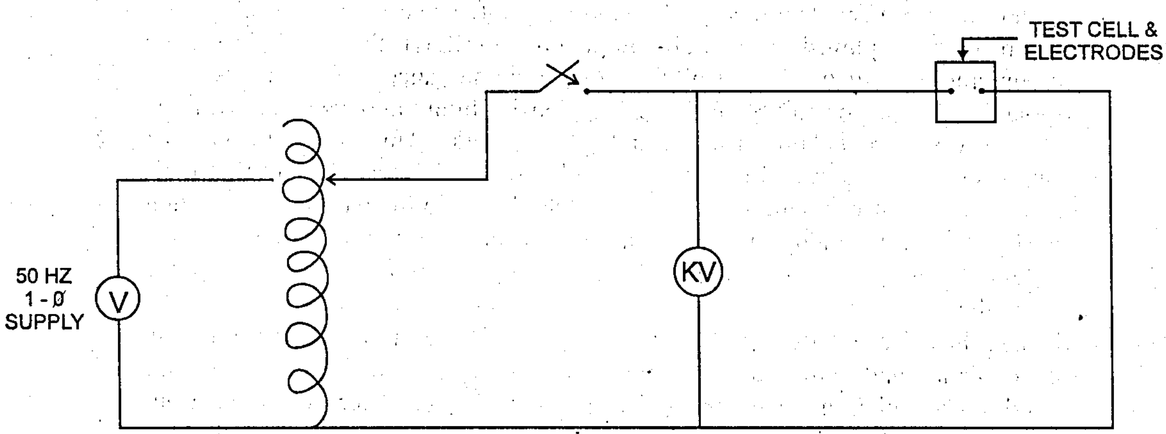


Fig. 5.1: Schematic Representation of a High Voltage Oil Tester

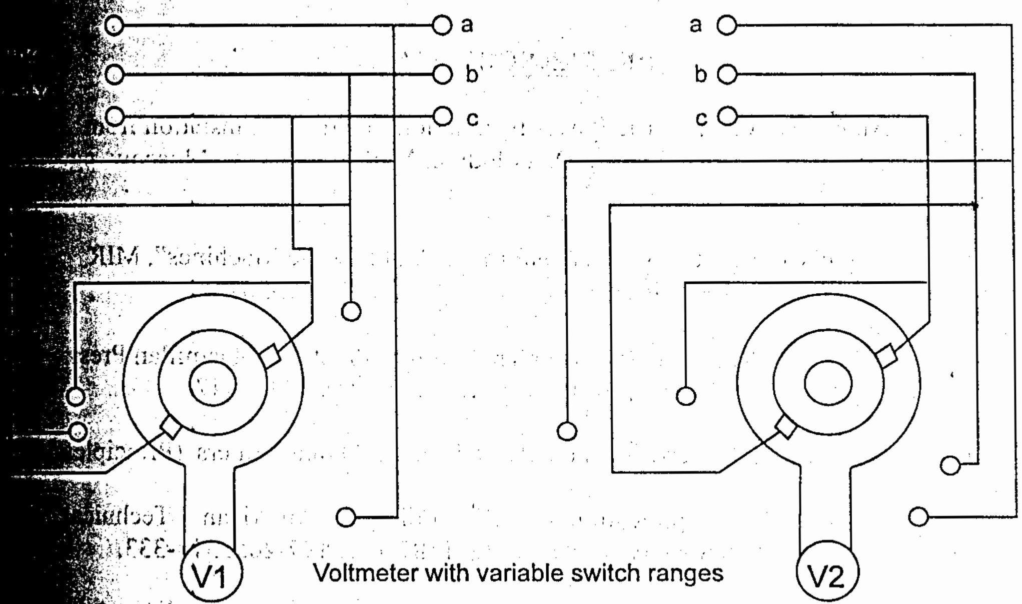
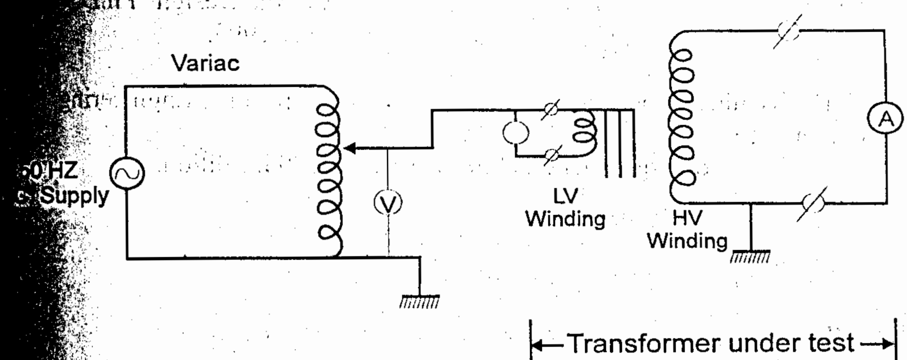


Fig. 5.2: High Voltage Test Circuit



.3: Applied High Tension Test Circuit

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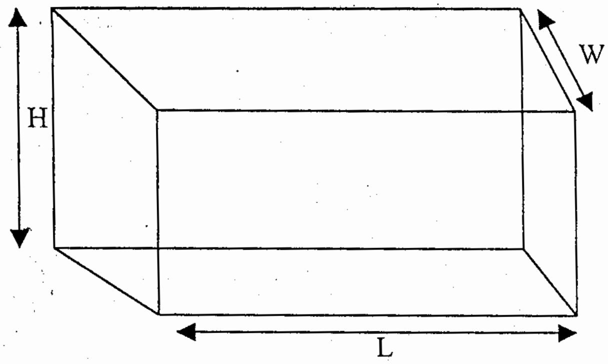
APPENDIX A



Figs. 5.3: Typical transformer fence dimensions
For 100 – 500KVA: L 15FT, W 10FT, H 10FT (FENCE)
For 100 – 500 KVA transformer plinth: L 5ft, W 4ft, H 4 ft.

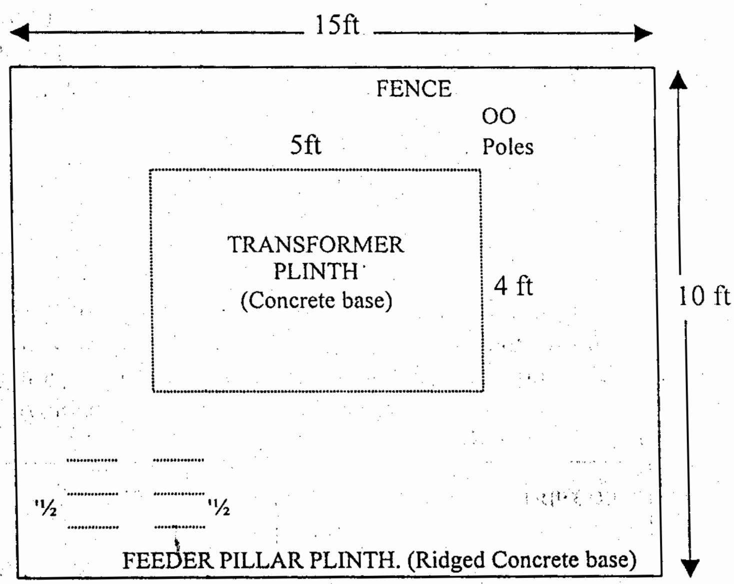


Fig. 5.4: Plan outlay for fencing/plinths