ISSUES AND PRACTICES IN SELECTION AND OPERATION OF DISTRIBUTION TRANSFORMERS

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Selection Criteria of Distribution Transformers

- To meet the load requirement – duty cycle
- Meet the performance requirement- losses to be minimum – efficient operation
- Compatible primary and secondary voltage- tap changers
- Vector group connection
- Meet the statutory requirement- safety of personnel, equipment and environment
- Minimum maintenance requirement
- Long operating life
- Over all minimum total owning cost (TOC)
Losses in Transformers

• When the transformer is not supplying load – No-load loss (also known as fixed loss, core loss and is due to Hysteresis loss and Eddy current loss)
• Hysteresis loss is a function of the material used for the core \( (P_h = K_h B^{1.6} f) \)
• The eddy current loss in the core is because of the induced emf in the steel lamination sheets and the eddies of current formed due to it \( (P_e = K_e B^2 f^2 t^2) \)
• Eddy current loss can be reduced by reducing the thickness \( (t) \) of the lamination
Losses in Transformers

• When the transformer is supplying load – No-load loss + losses due to load current
• Other losses {stray load loss (because of leakage fluxes of the transformer), dielectric (in the insulation of the transformer due to the large electric stress), ancillary}
• Thus, losses are: Constant losses (mainly voltage Dependant) and Variable losses (current dependant)
• For highest operating efficiency at a fractional load: constant losses equal the variable losses at any fractional load \( P_C = P_L \) but this design may not be cost effective. Iron losses are so low that it is practically impossible to reduce the full load copper losses to that value. Such a design wastes lot of copper.
Losses in Transformers

• Utilities to decide on the load factor expected in their system- utilities have different load factors so no uniform criteria could be given

• Core loss could be minimised by selection of material – (CRGO, amorphous), workmanship, magnetic field level and current density which are design parameters
Temperature rise

• Losses results in heat inside the transformer – raising the temperature of winding and cooling medium (mostly oil)
• Dry type another variant for locations where fire hazard requirements are stringent
• The temperature rise decides the rating of the equipment
• The temperature rise - a function of heat generated, structural configuration, method of cooling and type of loading (or duty cycle of load).
• DTs are now metered with data communication facilities it should now be possible to derive the duty cycle and peak loads to which the DT is subjected
Temperature rise

• The peak temperature attained directly affects the life of the insulations
• In the case of a.c. machines rating is expressed in terms of apparent power- poor power factors are thus injurious to the transformer
• Excessive reactive power demand increases the current handled by the machine and the losses resulting from it
There exists a possibility that Power transformers are switched in or out of the circuit depending upon the load to be handled by them (in case more than one transformer is available in S/S).

A distribution transformer has to remain in service all the time – calling for low values of constant losses – hence ‘all day’ efficiency of DTs is important (redundancy in DTs installation is not very common).

A better option is to keep constant losses very low to attain high all day efficiency.
Loss capitalisation- Total Cost of Ownership (TCO)

• Variable losses related to load and associated with revenue earned. The constant losses are necessarily borne to make the service available.

• Loss capitalisation in simple terms means - capitalize constant losses and variable losses and add to cost of the transformer to select the most competitive one, which gives minimum cost taking initial cost and running cost put together.

• In addition to the TCO considerations, increasing the efficiency of distribution transformers also results in environmental benefits and in a reduction of: CO₂, NOx and SOx emissions
Loss capitalisation- Total Cost of Ownership (TCO)

• Energy Management should have a concept of least life cycle cost
• The total ownership cost includes the initial purchase price of the transformer and all costs associated with the operation of the transformer over its lifetime.
Loss capitalisation- Total Cost of Ownership (TCO)

• Electrical utilities need to operate their networks more efficiently and to reduce the total running costs of equipment.
• TOC can be used as a tool to compare the offers, if made part of the tender document.
• Thus tendering practices followed at present need a review
Loss capitalisation- Total Cost of Ownership (TCO)

• TOC includes both the initial capital price and the capitalized cost of losses.
• TOC = Initial Cost of Transformer + Cost of the No load Losses + Cost of the Load Losses
  = IC + (A*Wi) + (B*Wc)

Where,
• IC = Initial cost of transformer as quoted by the manufacturer (Rs)
• Wi = No load losses of the transformer
• Wc = Load losses of the transformer

• TOC helps in purchase decision criteria to perform a lifetime cost analysis based on the capitalization formula.
Loss capitalisation- Total Cost of Ownership (TCO)

• Capitalization of losses is a method for assessment of distribution transformers price. However, a better understanding of applied factors and methods involved is needed. This method allows the total losses over the whole life cycle to be taken into account (termed as total owning cost, TOC). However, because of the many variables involved, such as inflation rates, peak loading duration, investment costs, etc., use of this evaluation method should be with proper judgment.
Loss capitalisation- Total Cost of Ownership (TCO)

• Above all, a well prepared procurement procedure and adherence to quality assurance plan may prove useful and will help to avoid misunderstandings between a buyer and a seller and should lead to optimum purchasing decision with losses kept sufficiently in focus.

• Energy losses cost is one of the several parameters, however it is not the most crucial.
Loss capitalisation- Total Cost of Ownership (TCO)

• The intended duty cycle and meeting other standard technical requirements are also the deciding criteria. At the same time it is important that the proven, standard products should be given due weightage.
Loss capitalisation- Total Cost of Ownership (TCO)

• Predictable overload, motor starting duties and other severe duties may be another criteria to decide. Along with the transformers’ cost the associated cost of mounting structures, protection system, O&M cost, space requirement and particular location (indoor, crowded places, geographical terrain) are also worth mentioning. Hilly terrain need special consideration as far as total transportation weight is considered.
Loss capitalisation- Total Cost of Ownership (TCO)

• The Power utilities are in a regulatory environment. Main concerns while creating infrastructure and making capital investment are that of safety, meeting the specific requirement and overall economy of operation.
Loss capitalisation- Total Cost of Ownership (TCO)

• Distribution transformers are procured with a view that under reasonably normal conditions of operation they would serve satisfactorily for about 25 to 30 years without any appreciable degradation in performance and comply with the requisite safety norms.
Loss capitalisation- Total Cost of Ownership (TCO)

• Thus it is clear that a Utility has to meet the service, statutory and economic requirements and strive for a good return for the investment made. In case of establishment of distribution transformers (DTs) the investment/capital is needed for initial cost, operation and maintenance cost and also the “recurring expenditures” which are on account of the “No Load Losses (fixed losses)” and “Load Dependent Losses.” These losses are a cost to the utility over the life cycle of the transformer.
Loss capitalisation- Total Cost of Ownership (TCO)

• While evaluating the offers for DTs the cost conscious utilities, as a good practice resort to the concept of total owning cost (TOC) of transformer. Based on pre-notified method of calculation, TOC is one of the concepts exercised to make a selection of the offered distribution transformer by different vendors where the values of losses are also evaluated and accounted for in the overall cost.
Loss capitalisation- Total Cost of Ownership (TCO)

• It is a commercial condition and as per the utility operating and financing norms the values of parameters A&B are specified by the utility in their tender document for evaluating the offer.
• Care need to be exercised in determining the value of parameters A&B and weigh the TOC with the specific requirements of a particular application.
Loss capitalisation- Total Cost of Ownership (TCO)

• In addition to that, safety, reparability, flexibility of operation, interchangeably of the equipment and the protection requirements also need to be examined before arriving at a final decision.

• Some of the utilities/industries decide the offer based on achieving the maximum all day efficiency of operation.
Loss reduction in Network

• A major potential for loss reduction in Distribution transformers
• Higher efficiency calls for increase the conductor cross section thus increasing copper and aluminum consumption so weights and dimensions will increase in most cases.
Loss reduction in Network

• All cores to be constructed with low hysteresis and eddy current losses
• Magnetic flux densities are to be kept well below the saturation point to prevent core overheating by doing this there is improvement in performance and over all gain => a large energy saving gain
• Losses in distribution system are quite high - a small efficiency increase can result in significant energy savings over the lifetime of the transformer.
Amorphous Core Distribution Transformer (AMDT)

• An amorphous core transformer (AMDT) uses amorphous metal alloy strips for its magnetic circuit. This allows building transformers with very low no-load losses (up to 70% less than conventional types).

• Because of the flexible structure of the core, the capacity of amorphous core transformers is currently limited to some MVA.

• Amorphous core transformers are 5 to 20% heavier than conventional transformers of the same capacity.
Long life cycle and continuous operation

- Distribution transformers have a life cycle of 25-30 years or more. Thus, a small energy efficiency difference can add up to significant savings.
- But procurement Division is separate from operational division, and procurement cell goes for lowest initial offered cost concept, this needs to be changed.
Harmonic currents increase losses

• The energy efficiency of a transformer is badly influenced by ‘harmonic currents’. Harmonic currents are distortions that are inherent in the system, efforts are made to keep them as low as possible. Harmonic currents result in an extra energy loss in distribution transformers.
• Harmonic currents also reduce a transformer’s lifespan.
Harmonic currents increase losses

Where harmonic content are more, replacing an existing transformer with a standard unit rated at a higher kVA level is generally not a good approach, instead the transformer which could handle the harmonics should be placed.
Harmonic currents increase losses

When utilities generate voltage, it is free from harmonic distortion. Non-linear loads inside home or business complex generate harmonics. These loads draw current in a non-linear fashion, which creates harmonics. Harmonics will distort the voltage wave shape.
Harmonic currents increase losses

This voltage distortion can cause problems for other equipment using the power. A common problem of harmonics is that they cause overheating of electrical equipment. This can be harmful to neutral conductors, transformers, motors, generators, and power factor correction capacitors.
Major Safety Precautions for Distribution Transformers

• Must be protected from violent explosions.
• Ensure that it has no internal fault when putting in to service, especially the repaired one.
• Earthing, fusing arrangement to be checked on regular basis.
• It is a better option that aged transformer with poor performance record be replaced by a high efficiency new transformer.
Other Common Issues

• Manufacturing Defects- low factor of safety
• Inadequate Design – cost cutting approach
• Transformer Tank Size - Inadequate clearance for free circulation of oil
• As per the application requirement => Percentage Impedance (Mechanical Strength of Coil)- design transformers with increased impedance to increase the short circuit withstand capacity of the transformers
Other Common Issues

• Usage of Improper size of fuse wires (HG fuse and feeder fuses)
• Improper Maintenance
• Use of improper diaphragm in the explosion vent
• Diversity Factor for loads, capacity decided based on DF, but in case of power shortage diversity is missing and almost all the load come simultaneously, exceeding the DT capacity
• Tree fouling on lines
• Non maintenance of Breather
Other Common Issues

• Non removal of water condensate in the transformer - Due to absorption of moisture from atmosphere for a long period large quantity of water may be collected in the transformers. This may lead to hazardous situation.
Other Common Issues

• Oil leak in bushings or any other weak part of the transformer
• Low Oil Level – theft of oil as also of copper
• High Oil Level - transformer may fail due to high pressure by explosion of vent pipe.
• Low BDV of the oil
Other Common Issues

• Heavy lightning - If the HT LAs fails to divert the direct stroke or surges due to discontinuity in earthing system, this will result in either failure of HV winding due to surge voltage or bursting of HT Lightning Arrester itself.
Other Common Issues

• Bushing Flash Over- Dust and chemicals carried away with air and deposited on the bushings will reduce the electric leakage distance causing flashover.

• Failure due to bird fault
Other Common Issues

• Load imbalance induces a circulating current in a delta winding, so balancing loads results in lower losses.

• Conductor upgrade by the introduction of continuously transposed conductors reducing eddy current losses and allowing better packing density of the winding.

• Distribution transformers today can be more efficient than ever, and at the same time economical.
General checks prescribed for Quality CRGO used in DTs

• Invoice of supplier.
• Mill’s certificate
• Packing List
• Bill of landing.
• Bill of entry certificate by custom.

Above all, the most important is a professional approach and accountability at different level, either in planning, purchase, execution or in operation.
THANK YOU

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