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Importance of Capacitance and Tanδ in the Life of EHV Equipments

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I. INTRODUCTION

In the technological world, use of good quality material/equipment, economy in design, sleek in shape and other quality factors calls for a high reliability of equipments during service to be rendered. Increasingly, present day quality control requirement in production/use and on site tests imply not only reliability but convenient in operation also. During the past years, a lot of new monitoring techniques have been developed. In other words, customer and manufacturers, both are forced to modify the system of equipment monitoring in scientific way by way of regular checkup of equipment. It not only indicates condition of health but also avert its failure giving relief to its user in terms of consequential failure/damages i.e. saving time and money. In the recent times, Measurement of Capacitance and Tan delta has been added in monitoring of equipments in EHV Transformers/Reactors and Bushing, CVT/CT, CBs, Large size motors, and Power cables. Deviation of C & Tanδ parameters indicates obviously addresses a threat to equipments like Accelerated aging, and premature failure.

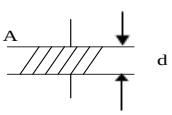
In this article effort has been made to understand the importance of measurement of capacitance and tanδ in the requirement of EHV class.

II. CAPACITANCE AND TANδ MEASUREMENT

In other terms this test can also be called as 'Signature analyses of any tested equipment**.** If DGA of oil indicate increase of H2 gas it means increase in Partial Discharge & development of sparks, this spark may be within the windings or may be between core to body Then it becomes imperative to locate the fault within the equipment. Many times the partial discharge in intermittent depends upon system parameters i e. source such as voltage, frequency, harmonics level etc. In case of large transformers if fault is deep within winding then becomes hard to locate. But in case of CT/CVT/CBs instead of repairing it is always better to replace the identified equipment. For example capacitor of CB, stack of CVT, Bushing of transformer when identified can be replaced early before it causes a major damage and sequential loss. Figure 1 gives detail of internal Structure of EHV Equipment.

Capacitance

Capacitance of any equipment C = E
A - Area of Electrodes/plates (A / D)



d – Distance C_x/d
E = E_o x Er - Er - Relative permittivity

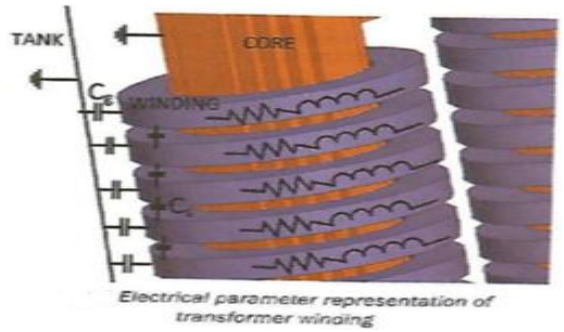
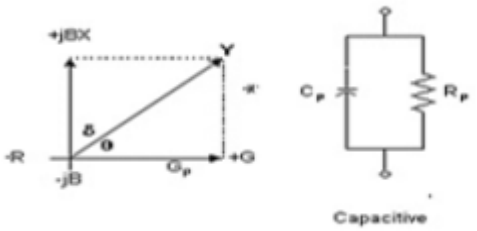
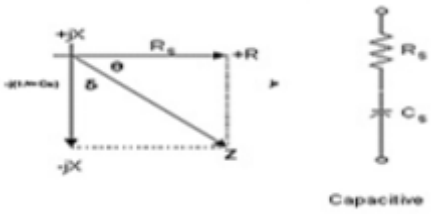


Fig. 1. internal Structure of EHV Equipment.

Dissipation Factor



For parallel Circuit: Tanδ=Ir/Ic = I/wCpRp



For Series Circuit: Tanδ = wCsRs

Power Factor

Tanδ = Sinδ/Cosδ
$Sin^2\delta + Cos^2\delta = 1$
$Sin\ \delta = 1/\sqrt{1+Tan^2\delta}$
$COS\phi = Tan\ \delta/\sqrt{1+Tan^2\delta} = Icx/I$

III. WHY CHECK C AND TANδ

Capacitance of equipments changes due to high level of harmonics, high/low frequency, Voltage Surges, Low/High

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operating conditions, Extreme cold/hot conditions, Moisture content & age.

a) During Manufacture: Tanδ is an excellent tool to record the insulation quantity. Tanδ of individual coil s, assembled phases and complete equipment provides a measure of insulation quality at each stage of manufacture.
b) During Service: A periodic check on Tanδ and capacitance of high voltage equipment help in assessing.
   - Rate of deterioration, failure can be predicted and corrective action can be taken.
   - Maintenance / overhauling schedule could be fixed so that an unexpected breakdown does not hamper the production.
   - Machines insulation can be repaired before actual flash over takes place. Flash over can damage the equipment and this means a high cost of replacement.
   - After repaired, quality of insulation can be checked before taking it back to service
   - Procurement of replacement material can be planned. This reduces the inventory as well as delay in procurement at the last minute.

Skin & Edge Effect

A circular conductor has a tendency to have more current density at outer surface. Similarly Edge Effect means current density more at Edges. Thus allows deformation in shape on account of stress and by virtue of age , stress, fluctuations.

Power factor measurement has often been used as tool estimate paper moisture content. As during service insulation may absorb moisture form atmosphere or through oil if preservation/breathing system of equipment is faulty. Electrical stress in equipment also converts copper and aluminum to CU2O3 and Al2O3 and further adds oxidation process. On account of corrosion and partial discharges, It further generates free Carbon & Hydrogen group gases. CU2C3 and Al2O3 formed accelerated the corrosion. Figure 2 indicates start of equipment insulation and has tendency to increase. Thus Concentrated stresses invites premature death or faster rate of deterioration.

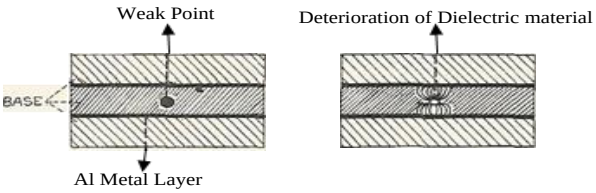

Fig. 2. Indicates start of equipment insulation and has tendency to increase.

IV. When to check C and Tanδ

- During manufacture preferably at each stage
- On service
  - Frequency of capacitance and Tan delta test will depend on rate of change of Tanδ and versus time (month/year)
  - If the slope of C/ Tanδ curves voltage and time increases between successive measurements, it is an indication that measurements to be repeated frequently.
  - Frequency of testing can also depend on history of past failures on similar make machines.
  - Will depend on the environmental conditions. More temperature/humidity/pollution would require more frequent measurement of Tanδ.

V. Recommended value of C & Tanδ

Capacitance. As recommended by supplier or as per test report. However maximum change of 6% on either side at any stage, equipment needs replacement.

Figure 3 Indicates stress on graded insulation of EHV equipments. Damage at any point will cause change & spread further.

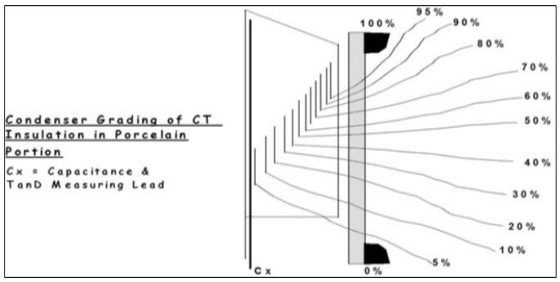

Fig. 3. Indicates stress on graded insulation of EHV equipments.

From 2000 to 2014 there has been a failure of 65% in equipments upto 765Kv on a/c of DGA & Tan δ Violations. DGA also starts violation when there is change in C & Tanδ identified in other words all the 3 are complementary to each other.

In case of lightening arrestors as 3rd harmonic leakage current increases. Tanδ changes

a. Capacitance

1. As per factory test reports ±6% at site
2. A change in value and beyond ±10% gives a definite indication that inside detritions has started & need to be replaced.

For Example – 400 KVT -4400pf
Sec – 110/√3
Basic circuit of CVT is as shown in figure 4.

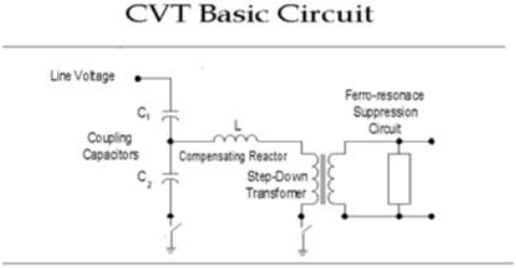

Fig. 4. Basic circuit of CVT.

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Change in C1 by 0.35 to 0.45% failure/puncture of one capacitor inside will increase the output by 0.22-0.28V, thus in place of 110/√3 on secondary will read as 110.28/√3V

If again converted on HV side, side will read as 402.00kV

In similar way, failure / puncture of one capacitor element in C2 will decrease the sec. voltage by 5 to 6% that is 3.2 to 3.8v. This means CVT will read as >412.0. A false tripping or indication leading to confusion in analysis. Utilities are facing failure rate of about 3% on CT and PT/CVT on account of such deviation still this reduction in failure only on account of proper coordinated routine checks carried out time to time.

b. Tanδ

Max^{m} value of Tanδ is 0.007 and if there is change/ incremental rate of .001 per year, the equipment needs replacement. Value of Tanδ is 0.002 at commissioning. Though there is no definite defined relationship between C & Tanδ, but both are complimentary to each other during service and moisture inrush also add to problem. Change in Tanδ may also be due to aging.

Other reason of change

Development of slow fault or low energy fault

- Increase in partial discharge i.e. insulation has started degrading
- Inrush of moisture
- Wrinkles in Al. foils of capacitors
- Week/poor quality of soldering – Tan δ effected
- Wrinkles to craft paper

Figure 5 shows equipment failure on account of dielectric deteriorations.

Relation of Tanδ**,** BDV & moisture play very important role in EHV equipments in nut shell they are complementary to each other. Increase of moisture decreases the value of BDV value of Oil, decreases C & Tanδ. As a result more risk of failure.

Figure 6 indicate relation between Tanδ, BDV & Moisture. In other words they are complimentary to each other. Inrush of moisture will increase tanδ, reduce capacitance value, increase partial discharge. Hence it always important to check BDV of oil and polymerizing index of equipment and should be more than 1.4.

Thermal Imaging

Further deviation can be confirmed by thermal image of equipment. Figure 7shows image of CT, When Deviations Are Noted.

Test Procedure

Capacitance and Tan δ method of measurement is based on the principle of schering bridge by applying 10KV. It measures C as a global average of equipment. Thus slight decrease in C represent deterioration of dielectric.

History Record

Although there are no standard guidelines, unusual changes against earlier measurement say more than 10% indicates insulation is quickly degrading / deteriorating**.** Comparing of results with identical machines. i.e. of same lot would also provide help to establish /conclude. Initial values are treated as signature.

(a)

(b)

(c)

Fig. 5. Equipment failure on account of Dielectric deteriorations.

Limitations and Care

Being very sensitive measurement and other equipments charged close by. Due to induction effect the results obtained many a times can be confusing, thus almost care should be taken while measuring and proper record maintained for comparison. It is also preferable that equipment used should be same every time to avoid equipment error. Test equipment should be calibrated and suitable correction factor applied for error and temperature. Connection should be clean and tight.

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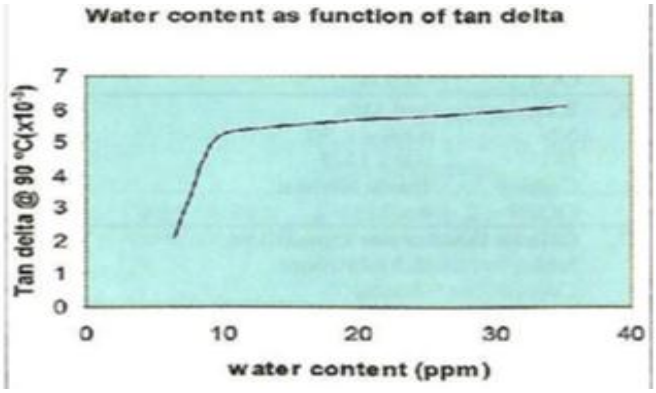
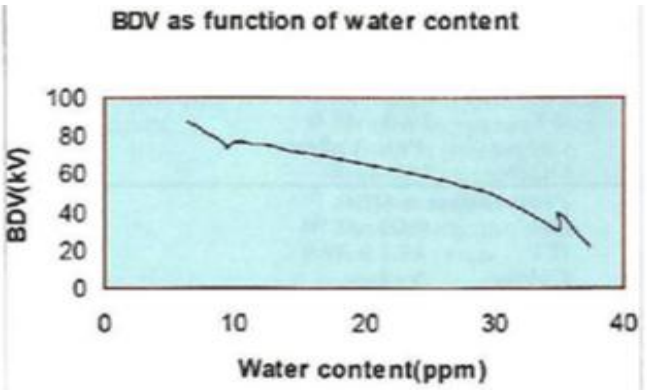


(a)



(b)

Fig. 6. Relation between Tanδ, BDV and moisture.

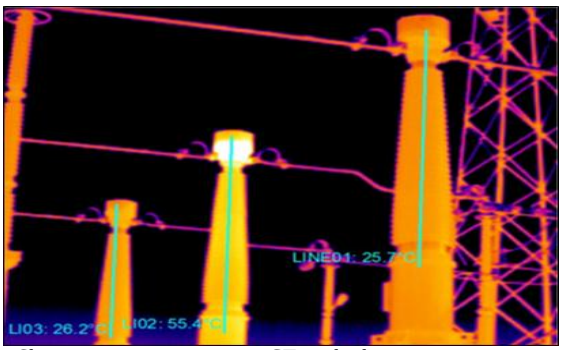


Fig. 7. Shows temperature rise in CT with thermo vision camera which Violates C & Tan δ.

VI. CONCLUSIONS

a. C and Tan δ are not only function of voltage and frequency but also a function of Temp and moisture contents.
b. It makes Possible to check/reduce break down costs.
c. Investigation characteristic of various class of insulation over period of time i.e. predicting life of machine.
d. In this computer age, each equipment should be identified by unique ID, proper record to be maintained.

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