APPLICATION NOTE

Preventive diagnosis based on Capacitor Transformer condition

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INTRODUCTION

We will explain the method Arteche has developed in order to get to know the state of the HV insulation on Capacitive Voltage Transformers, in an easy and reliable way and without interrupting the power supply.

This information is crucial for decision making in the Operation and Maintenance of High Voltage equipment and also to more efficiently direct future investments.

This type of transformers is widely used mainly in HV transmission systems, due to their better cost-effectiveness compared to inductive VTs.

Diagnosing the insulation will ensure the safe performance of the network, preventing and reducing unplanned disconnection periods.

A CVT is mainly composed of two elements: a capacitive divider and an inductive voltage transformer.
The Capacitive voltage divider is what provides the high voltage insulation, whereas the Inductive VT is a medium voltage step-down transformer which provides the outputs for metering and protection functions.

What we see from the outside is a tank which houses the transformer, and over it, 1, 2, 3 or even 4 insulators, depending on the voltage level of the line. Inside the insulator columns we find a number of capacitor units connected in series, which if the failure is in C2 the reading will go to the negative area.

divide the High Voltage present in the line in proportional smaller voltage levels, all the way to earth.

For a 123kV CVT we may find around 75 to 100 individual capacitors inside the single insulator, for a 245kV unit it may be 150 to 200, whereas for a 400kV unit the number may reach 300 capacitors or more, distributed through the usually 3 insulators.
The intermediate VT takes the voltage level from a tap at 5 to 20 kV, in the lower insulator, and then further transforms this to the desired single-phase secondary voltage, usually, 58V or 63 V. 100/V3 V or 110/V3 V.

The capacitors above the tap are named C1 and go all the way to High Voltage and the capacitors below are named C2, from the tap to earth.

Unfortunately, some of the individual capacitor units may decay with ageing, unexpected voltage stresses in the line, etc.

When one of these capacitors fails, the voltage divider is not balanced anymore, and therefore the voltage level at the intermediate tap is not the expected. The secondary voltage will not be proportional to the primary voltage anymore, causing an error in the accuracy reading.

If the failure takes place in C1, above the intermediate voltage tap, the error will move to a more positive reading.

Furthermore, once the individual capacitors start to fail, the rest of the units must withstand an increased proportional voltage. We can say that the entire high voltage must be shared by less capacitor units, over-stressing them.

Due to this, more capacitors may fail, increasing the insulation breakdown rate exponentially.

In other words, the failure of the individual capacitors causes two main unwanted effects:

1. unreliable readings in the metering and protection systems, and
2. more critical outcomes, as complete failure of the CVT with possible catastrophic effects.

Knowing the state of the capacitors, and the degree of degradation will help us:

1) Be aware of the reliability of the readings for the measuring and control systems, but also
2) anticipate the failure of the unit , therefore avoiding undesirable consequences on surrounding equipment or personnel safety.

So, it is clear that the accuracy verification in a Capacitive VT is a very useful tool for the diagnosis of this kind of transformers.

A deviation from the precision of a TTC is directly related to the damage in its insulation and that as soon as there is a deviation in the precision, the deterioration of the transformer will have irretrievably begun.

SCOPE OF APPLICATION

Utilities are more and more aware of the importance of a preventive maintenance, and the advantages it provides. There has been an evident evolution on asset maintenance practices over the last years.

Initially, the approach was "passive", simply replacing the unit once it reached its expected lifetime. The problem with this system is not knowing if the unit could have lasted some additional years, losing that extra operational time, or worse, being unaware of a possible premature failure.

This scenario can be improved by applying certain periodic maintenance actions to my assets, but usually these programs define the same actions to all units regardless of their state. This is better than doing nothing, but you still run the risk of catastrophic damage or not enjoying the life of the asset due to premature replacement.

A further advance is applying a condition-based maintenance, or even better, a risk-based maintenance, considering the problems that this particular asset may cause if it fails.

This is where our method comes in; a method that will allow us to know exactly the real state of the insulation of the CVT and therefore will help to make SMART decisions based on data.

The usual practices carried out for a CVT diagnosis include capacitance measurements, tangent delta, accuracy testing…. and will depend on each utility.

In general, it involves at least one of the following:

- Planned outages – in traditional maintenance it is essential to disconnect the area where the diagnosis will be carried out in order to work and manipulate the HV equipment safely
- It will also involve Working at heights, using elevating machinery in order to reach the unit's secondary terminal box, or even the primary terminals, which for 400kV and 500kV units is pretty high.
- Other practices may require:
    - Working with high voltage generating equipment, usually 4 to 10 kV, in order to achieve testing voltage
    - Using HV testing equipment to simulate actual operating conditions.
    - Altering the secondary loads or circuits
    - It may also be necessary to lay cabling or wiring through the substation in order to connect different measuring equipment
    - Or using a calibrated reference standard which has to be deployed from a local laboratory.

All of this requires time, technical and human resources and inoperative installations, which, bottom line: is costly.

Arteche's aim was to develop a system which allows knowing the state of the insulation with as little fuss as possible.

PROPOSED SOLUTION

The method is based on the electromechanical characteristics described at the beginning.

As we mentioned earlier, a 400kV CVT may have around 250 -300 capacitor units. The failure of 1, 2 or 5 may go undetected, especially if they are located in C1, the part of the divider with more units, unless the measurements are done with a very accurate and reliable system.

Substation SCADA already monitor current and voltage, but they are not accurate enough to detect the early stages of ageing, when only few capacitors have failed and will only see the damage when it is too late and there is no time for reaction.

Taking into account that the break down speed grows exponentially, the greater the uncertainty in the measurement, the less time will be to react before the final failure and prevent the explosion.

This method allows to determine, with the minimal uncertainty (close to laboratory accuracy levels), the error of all capacitive transformers in a substation while in service.

This means, the accuracy is measured under ACTUAL operating conditions, with rated primary voltages and taking the readings from the actual secondary voltages.

There are no models or simulations.

Identifying and periodically tracking the accuracy deviation of a CVT will give us an idea of how the insulation may be evolving over the years.

This gives the opportunity to set up a long-term planning for the lifetime of the equipment. It also allows performing predictive maintenance and long-term management.

Disregarding the issues which may appear initially, the unit will remain in good condition for an undefined period of time, with stable accuracy class, as when tested in the factory. After some time, the accuracy will start to fail, as the capacitors degrade.

With this method we will detect in the early stages which units still perform adequately, and which are starting to have problems, as well as the degree of damage.
It will give time to decide what to do, and when to do it.

CONCLUSIONS / BENEFITS

As an alternative to all the previously mentioned requirements, our CVT diagnosis method:

- Does **not require outages** or machinery, allowing the power supply to continue, uninterrupted. There is no need to plan or coordinate outages. No need to access the unit's terminals.
- For **all CVT brands**, and voltage levels
- **Non invasive** – The unit is not manipulated
- Will **not become obsolete** or need upgrading.
- **No need for cable** laying through the substation
- **Reliable** since transformers that the method has identified as damaged have been later analyzed in the laboratory and afterwards opened and dismantled in the presence of third-parties, confirming the validity of the results obtained by the diagnosis.
- **Efficient:** It is possible to analyze all the transformers in a substation in a relatively short period of time.

As a summary, we can say that the method we are presenting allows, with a high degree of reliability, without risk during the procedure, in a very flexible way and with a very low execution cost, to help the electric utility in the management and planning of their investments, optimizing your capex and opex.

Moving together

AN_Capacitive Diagnosis_EN
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