TIME TO RECONSIDER VTS IMPLEMENTATION FOR A BETTER RELIABILITY

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ABSTRACT

In the smart grid deployment, more and more voltage transformers (VTs) are used to provide voltage measurements, for example for power measurement. In traditional switchboards, VTs were identified as a possible weak point because of their sensitivity to environmental conditions. To limit the consequences of a possible failure of the VTs, medium voltage fuses were often used to break the fault current and isolate the VT from the rest of the switchboard still being live. The purpose of this paper is to describe why modern solutions with voltage transformers without the application of medium voltage fuse are now more reliable than traditional ones.

Keywords: *Voltage transformer, fuse, medium voltage network.*

INTRODUCTION

Smart grids have two main objectives. One is to optimize the relation between the demand and the supplying of energy. The second is to provide the necessary conditions to integrate more distributed and renewable energies. Comparing the two-way flow that is needed for these objectives with the simple one-way flow still valid with centralized energy production, the challenge is big. Control and monitoring will increase to properly manage the real-time connections to the grid. For that purpose, more and more sensors will be used.

The online MV voltage monitoring becomes essential and the impact of voltage transformers on the MV switchgear is more and more important.

The choice and definition of voltage transformers and their accessories is one of the key factors impacting the reliability of the system.

TRADITIONAL VOLTAGE TRANSFORMER APPLICATION

Currently, for some applications, the use of medium voltage fuse in association with a voltage transformer is required [Fig. 1]. The function of the medium voltage fuse is to protect the medium voltage system by the consequences of a failure of the voltage transformer.

Fig. 1. Typical MV VT including fuse protection

In public distribution HV/MV substations, VTs with fuse protection were commonly installed in incomer cubicles but rarely in outgoing feeder cubicles.

VOLTAGE TRANSFORMER STRUCTURE

There are two types of Voltage Transformers with different wiring: phase to phase connection and phase to earth connection

The VT structure [Fig.2.] consists of four main components:

- a primary winding or MV winding
- a secondary winding or LV winding
- a magnetic core
- an insulating material

Primary winding

The primary winding may be connected between phase and earth or between two phases of the medium voltage system. It is a linear winding of enamelled wire of reduced size, the diameter of which is generally less than 0.4 mm. the manufacturing process involves a cylindrical or squared rotating support and includes a supplementary insulation made with sheets of insulating material arranged between the layers.

The primary winding is permanently connected to the MV network and it is, therefore, subject to all voltage variations (i.e. fault, overload…).

Secondary winding

The secondary winding is placed between the primary winding and the magnetic core. The secondary output terminals are connected to the measurement or protection devices. A VT may have one, two or three secondary windings which are interdependent, depending on the type of connected device, measurement or protection.

It is a linear winding of an enamelled wire also made on a cylindrical or squared support.

Magnetic core

The magnetic core induces the voltage from the Medium Voltage circuit to the Low Voltage circuit.

The magnetic core could be a silicon steel C-Core strip wound, impregnated and cut into two halves or an assembled core.

Insulating material

The main insulation material ensures insulation and protection between the Medium Voltage circuit, the others VT components (Low Voltage circuit and magnetic core) and the environment in which the VT is installed, i.e; Switchgear.
The insulation material also has a mechanical function.
The main insulation is generally in synthetic resin (epoxy resin or polyurethane resin) and as all organic materials is subject to aging and changes in the dielectric properties and mechanical characteristics depending on the variation of the environmental conditions and including the temperature.
Special attention should be taken in the choice of synthetic resin and the use of casting system with high glass transition temperature is essential to achieve high quality standards and a long life expectancy.
For application with long term stresses the use of epoxy resin is recommended rather than the polyurethane resin

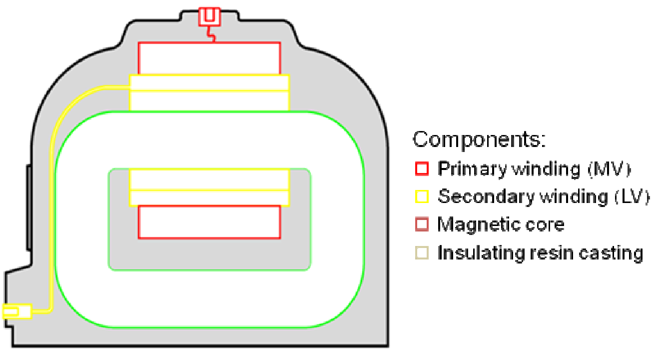

Figure 2. Cross sectional view of a VT

RELIABILITY OF RECENT MODERN VOLTAGE TRANSFORMERS

In the instrument transformer development, the mechanical functions and electrical performances can now be optimized by an extensive use of high technical 3D design.

In recent years the development of insulating materials and the improvement of industrial processes allowed for an increase in the quality of voltage transformers and, as a consequence, an increase of service operation of the products.

The whole system of resin preparation and casting may be fully controlled.
The control and fine tuning of industrial process is achieved by using pervasive sensors, with the possibility of checking all the critical parameters during the preparation of components, pre-mixed materials and casting process.
All the data may be logged and stored for feedback purpose.

The primary winding, which is the most critical component of voltage transformers, may be manufactured using computer controlled machines that monitor all the critical parameters (i.e. rotation speed, tensile strength) and assure the correct disposal and correct number of turns of enameled wire and the interlayer insulation sheet.
Consequently the electrical field is uniformly distributed and localized stresses that could impact the quality of the transformer during its opeartional life are avoided.

PARTIAL DISCHARGES MEASUREMENT

As explained before, the insulation material plays an important role for the longevity. It is of high interest to check it at manufacturing stage. The standards used worldwide, IEC and IEEE, require the measurement of partial discharges as a routine test to verify the quality of insulation of voltage transformers.

Test according to IEC 61869[1] [2]

After a prestressing voltage application performed during the power-frequency withstand test (procedure A) or an application up to 80 % of the power-frequency withstand voltage for not less than 60 s (procedure B), the partial discharge test voltages are reached, and the corresponding partial discharge levels are measured in a time within 30 s.

VT type	PD test voltage (rms)	Maximum PD level
Phase - Ground	1,2 Um	50 pC
	1,2 Um/√3	20 pC
Phase – Phase	1,2 Um	20 pC

Table 1. IEC Requirements for VT partial discharge tests

Test according to IEEE Std C57.13-2008 [3]

In its new revision, IEEE standard C57.13 defines the partial discharge measurement as a routine test with the following test procedure:
If made during the applied or the induced test, complete the dielectric test and then reduce the voltage to the established level of 1.05 times the maximum system voltage; hold for 1 min, and take the measurement at the end of the 1 min period.
If a pre-stress test is made, raise the voltage to the pre-stress level, 1.15 times the maximum system voltage for line-to-ground voltage transformers and 1.35 times the maximum system voltage for line-to-line voltage transformers, for a minimum of 10 s and reduce the voltage to 1.05 times the maximum system voltage and take the measurement at the end of the 1 min period.

Voltage transformers when tested in accordance with this instruction shall not exceed 50 pC partial discharge.

ADVANTAGES OF SHIELDED SOLUTIONS APPLIED TO VTS

New shielded and insulated solutions have been developed for voltage transformers ensuring the most efficient withstand to harsh environment because the insulating performances are not affected by any possible electrical field variation. As the external surface is coverd by a conductive layer, there is no electrical field line outside of the VT [Fig. 3]. Then, these types of VTs become totally insensitive to harsh environmental conditions (dust, pollution, humidity, temperature changes, etc ...), ensuring much longer service operation.

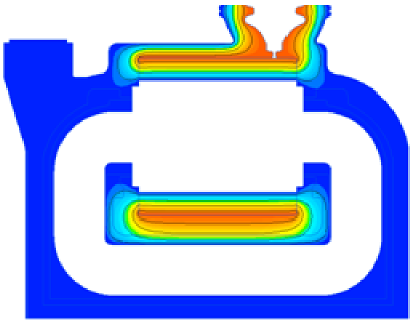

Figure 3. electrical field calculation in the screened VTs (the equipotential lines are plotted).

INFLUENCE OF NEUTRAL SYSTEM

The evolution of medium voltage distribution networks with the increasing use of systems with insulated neutral or compensated neutral by an impedance or Petersen coil automatically leads to a reduction of the magnitude of the earthfault currents. These low magnitudes of earthfault currents may become outside the range of medium voltage fuses operations. For these reasons the use of the medium voltage fuse associated with the voltage transformer does not bring any increase in the quality of service, but on contrary may itself cause failures because the fuse is air insulated and then sensitive to environmental conditions.

Comparing the risks, some Distributor Network Operators (DNOs) in different countries already have chosen to use VTs without MV fuses as a more reliable solution. For example, french DNO EDF moved from resistive neutral connection to compensated neutral connection in the nineties. Following this change of the neutral system, EDF issued a new specification HN 64-S-40 [4] to require VT without MV fuse, (clause 4.25). Low Voltage fuses are only required on secondary side.

MV FUSE DOES NOT PROTECT THE VT

An MV fuse does not protect the voltage transformer, it does not avoid the escalation from a small internal damage to a failure of voltage transformer finally resulting in a total failure of medium voltage system insulation.
In Figure 4, is shown an example of time-current characteristic curves of MV fuse for voltage transformers applications.
The fuse has a melting current of 12A at 0,1s and a melting current of 6A at 10s.
The voltage transformer which has a primary winding made by an enameled wire of diameter less than 0.4 mm, thus a cross section lower than 0.13 mm^2, cannot withstand the currents that are consistent with the intervention of the fuse that should operate. The primary winding will be damaged much before the fuse operates, leading to a failure of voltage transformer.

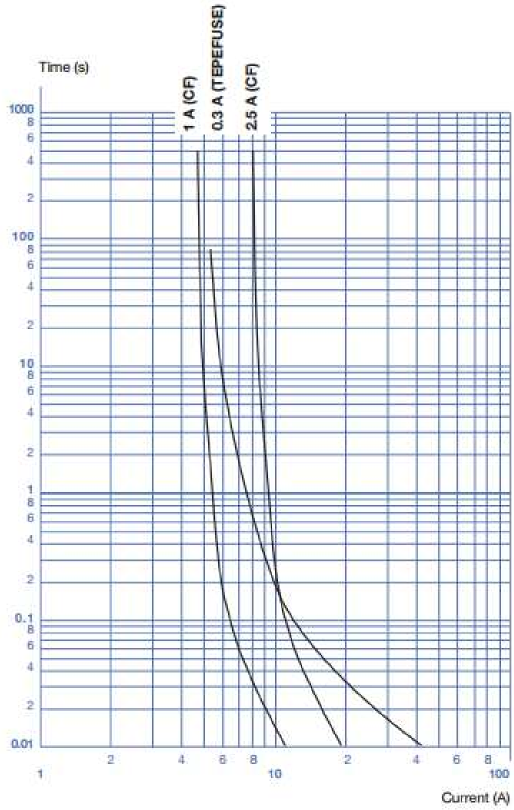

Figure 4. Time-current characteristic curves

VTs in Gas Insulated Switchgear (GIS)

Among the most reliable MV switchgear solutions are the typical primary Gas Insulated Switchgear (GIS). Their high reliability also relies on high quality VTs without MV fuses. Insensitivity of GIS to environmental conditions is ensured by gas insulation filled in a completely tight metallic tank. VTs are generally installed in the cable compartment [Fig. 5].

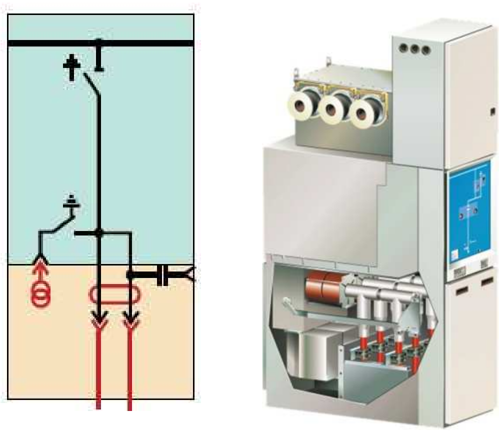

Figure 5. Typical GIS architecture including VTs without fuse

Figure 6. Typical GIS architecture including LPVTs

VTs in Shielded Solid Insulated Switchgear (2SIS)

The same level of reliability is provided with shielded solid insulation system (2SIS) applied to the main circuits including shielded VTs. There is no rupture in the shield continuity that ensures protection against harsh environment.

LPVT THE EVOLUTION IN THE VOLTAGE MEASUREMENT

Thanks to modern control & monitoring devices and digital protection relays, compact low power current transformers (LPCT) and low power voltage transformers (LPVT) can replace heavy traditional CTs and VTs.
Digital protection relays only need information concerning the primary currents and voltages and have the necessary capacity to process the measurement data.
For voltage measurement, the principle of a resistive voltage divider is chosen. This sensor provides a voltage signal proportional to the MV network phase-to-earth voltage. This measurement principle leads to inherently good characteristics in terms of large dynamic range and high linearity.
The main advantages of using LPVT [Fig.6] instead of conventional voltage transformers are:
- the reduction of size and weight that generates a smaller impact for their installation, generally resulting in a potential reduction of size of the switchgear or in the ability to multiply the measuring points allowing to increase the control of MV system
- the engineering and logistic simplification, as due to the wide range of application, only few variants of sensors are needed.

CONCLUSION

Looking for the best optimized solutions to meet the increasing need of MV voltage transformer instruments in the network, it has been shown that today, solutions implementing VTs without MV fuses become more reliable than the traditional implementations. A whole set of elements contribute to this result: large improvement in manufacturing processes, evolution of neutral systems, shielded solutions, new low power voltage transformer technology.

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