NEW GENERATION OF SWITCHGEARS WITH CABLE TESTING FACILITIES

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ABSTRACT

HV cables are required to be checked after installation, before being put into service and periodically during service life; in order to check proper installation, characterise initial and actual situation, to establish life expectancy and plan possible replacement, or even to locate faulty sections. This kind of work is considered as inspection or maintenance and the switchgears to which the cables are connected are on many occasions not designed considering the procedures used by inspection and maintenance workers.

On some occasions the procedures prescribe disconnection of the cables (totally or partially) from the switchgears for inspection or maintenance, to avoid any possible influence from or damage to other devices to which they were connected. This practise has other possible consequences such as possible mistakes during reconnection of the cables e.g. to the switchgear.

In other cases, it is necessary to have available specific testing facilities in the switchgear because the disconnection of the cables implies the destruction of the insulation i.e. handmade insulation on site; or there is a client specification

In this paper a cable testing system integrated into metal-enclosed switchgear, specifically designed for an easy-to-follow safe procedure without the need for direct access to the cable compartment is described, for those cases where cable testing facilities are required in the switchgear.

MAIN REQUIREMENTS FOR CABLE TESTING

A cable testing facility should be adapted to the procedure and testing equipment to perform the test on-site.

Testing equipment

The cable testing facility must be ready to connect some source used for testing the HV cables mainly by voltage injection. Under the general term of HV cable testing techniques, several standardised testing methods listed below may be used [see also References section].

- Insulation Resistance measurement (IR)
- HV dc pulses fault location
- HV dc leakage current measurement
- HV 0.1 Hz sinusoidal leakage current measurement
- HV ac leakage current measurement
- HV partial discharge
- Cable impedance measurement
- Phase identification

All these testing methods require appropriate testing apparatus and appropriate interfaces to facilitate their electrical connection to the conductors of the cables, installed or not, onto the switchgear. For this purpose, these apparatus are usually equipped with cables and terminals or crocodile clips. Additionally, interface adapters like bushings or insulated rods may be required to enable their connection through the solid insulated connectors placed at the end of the HV cables.

Procedure for cable testing

The second requirement is to consider which will be the procedure to perform the cable tests. This should be defined by the responsible of the installation in order to reduce the occurrence of possible mistakes which may have consequences for the persons involved or the installation itself. These procedures are normally obligatory by local regulations. In Europe we can cite for example EN 50110-1 and EN 50110-2 which are standards that give general requirements to establish safe procedures.

These procedures will depend on switchgear design, if it has cable testing facilities or not, and on cable termination designs; but generally the next steps should be done for voltage injection:

Disconnect the cable (all phases) from any source of voltage, for example by the use of switch-disconnectors at both ends of the cable to be tested.
Verify that the cable (all phases) is disconnected from any source of voltage.
Earth all phases on the cable side from where the cable is going to be tested, for example by the use of earthing switches.
Access injection points to place voltage source connection in the phase to be tested and place temporary earthing connections to the remaining phases.
Open earthing switch.
Inject voltage in phase to be tested.

PRESENT SOLUTIONS OF CABLE TESTING FACILITIES

In actual high-voltage switchgears several cable testing facility solutions can be found, which basically may be grouped in 4 types of system. Each having pros and cons which are described in this paper.

Type 1 – Systems without access points

In this type of switchgear, there is no specific point acting as a cable testing facility to connect the voltage source. Besides, the cable connectors have no access point (e.g. plugged elbow connector), so the only way to test the cables is to disconnect one by one (See Fig 1).

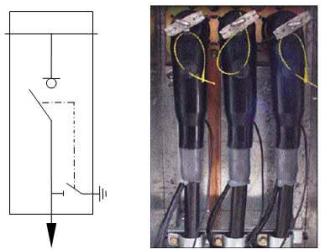

Figure 1 – System without access points

Cons:

- Cable installation conditions might be modified due to removal and reconnection of the cables.
- Necessary to access the cable compartment
- Necessary to use a tool to disconnect and connect the cables and a tool to connect the voltage source to the cable connector

Pros:

- The phases not under test are isolated from the phase under test connected to the voltage source.
- Switchgear insulation is not affected by voltage injection.
- Switchgear condition does not change.

Type 2 – Systems with access point in connectors

In this switchgear type, there is no specific point acting as a cable testing facility to connect the voltage source, but the cable connector (e.g. bolted elbow connector) has the possibility to connect the voltage source in a specific point by removing the back-plug of the connector, and placing an insulating test rod through it (See Fig.2).

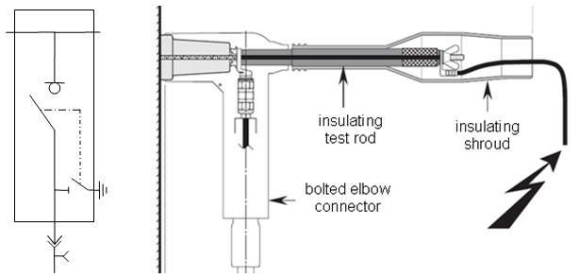

Figure 2 – System with access point through connector

Cons:

- Necessary to access to cable compartment
- Necessary to use a tool to disconnect and connect the back-plug and a tool (test rod) to connect the voltage source.

Pros:

- The phases not under test are isolated from the phase under test connected to the voltage source
- Cable installation conditions might be less modified than in type 1systems, because at the most, only the back-plug is removed.
- Switchgear condition does not change.

Type 3 – "British" systems with access point in switchgear

In this switchgear type, there are specific points acting as a cable testing facility to connect the voltage source, which are different from the cable bushings. These points belong to the earthing system of switchgear and, in service, are short-circuited by external earthing blades. To connect the voltage source, it is necessary to previously disconnect these earthing blades directly by hand (See Fig 3).

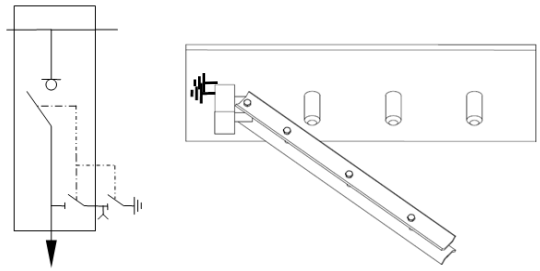

Figure 3 – "British" system and example

Cons:

- Usually necessary to isolate the phases not under test from the phase under test connected to the voltage source.
- Switchgear condition could change due to the necessity to open the earthing circuit system to connect the voltage source.
- It may be necessary to use specific isolated testing accessories to connect the voltage source.

Pros:

- It is not necessary to access the cable compartment, nor disconnect the cables, so cable installation conditions do not change.
- Cable facilities are placed in a specific compartment interlocked with a driving mechanism that operates the main earthing switch.

Type 4 – "French" systems with access point in switchgear

In this switchgear type, there are specific points acting as a cable testing facility to connect the voltage source, which are different from the cable bushings.

Similar to the type 3, these specific points belong to the switchgear earthing system. They are always accessible and there is no interlocking with the earthing switch.

In service, the specific points for voltage injection are short-circuited by an accessible external earthing bar. So, to inject the test voltage, it is necessary to open the earthing circuit of the switchgear, by removal of the short-circuiting bar (See Fig 4)

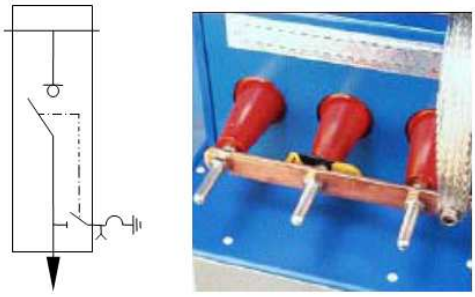

Figure 4 – "French" system and example

Cons:

- Switchgear condition could change due to the necessity to open the earthing circuit system to inject the test voltage.
- The removal and mounting of the short-circuiting bar needs a tool to achieve the right torque to fulfil the rated short-time withstand current, after mounting.
- Cable testing facilities are not placed in a compartment, and there is no interlocking with the earthing switch.

Pros:

- It is usually not necessary to isolate the phases not under test from the phase under test connected to the voltage source.
- It is not necessary to access the cable compartment, nor disconnect the cables, so cable installation conditions do not change.
- It is usually not necessary to use specific testing accessories to connect the voltage source.

Summary of cable testing facilities

As previously explained, and shown in following summary table 1, each type of system has different attributes implying advantages (coloured in green) and disadvantages, in terms of accessibility, safety procedures, tools needed and maintenance of the previous condition of the switchgear.

ATTRIBUTES / SYSTEMS	Type 1	Type 2	Type 3 (British)	Type 4 (French)
Grants original insulation condition of cable connections	NO	NO	YES	YES
Grants original continuity condition of earthing system	YES	YES	NO	NO
Requires access to the cable connections	YES	YES	NO	NO
Points of voltage injection inside an interlocked compartment	YES	YES	YES	NO
Necessity of specific tool to connect voltage source	YES	YES	YES	NO
Necessity of tool to assemble-disassemble parts with torque	YES	YES	NO	YES

Table 1 – Summary of attributes per cable testing system

NEW GENERATION OF SWITCHGEARS WITH CABLE TESTING FACILITIES

Features

Having reviewed the requirements of the cable testing facilities and the features of 4 types of cable testing system offered in the market, the following features are identified as desirable for a cable testing facility:

Safety: All initial conditions of the installation should be established after cable testing has been performed, therefore: Cable connectors should not be disconnected; and the switchgear earthing circuit should not be changed by disconnection or removal of part of it in order to avoid wrong torques and wrong connections, and to maintain the original switchgear condition.

Reliability: The access points for the voltage injection during cable testing should not be connected to the main circuit in service position to avoid stressing them or imply a possible risk for the operator during normal operations. Nor should these connections (access points) be part of the switchgear earthing circuit to avoid any influence on them from eventual short-circuit currents.

Accessibility: The cable testing facilities should be placed in a specific compartment different from cable compartment, and its accessibility should be interlocked with an earthing switch position in order to avoid the access to these facilities when not earthed.

No special tool: Cable testing facilities should be prepared to connect directly to the voltage source using its standard terminals i.e. crocodile clips; without the need for specific testing adaptors or testing rods.

Phase isolation: The 3-phase cable testing facilities should be isolated from each other in order to avoid the need to use additional insulating means; to isolate the phase under test from the other 2 phases during voltage injection.

Description

In order to improve the features implicit to a switchgear allowing the cable testing through it, in terms of safety, reliability, accessibility, necessity of tools and phase isolation during voltage injection, as described above, ORMAZABAL has developed a new cable testing facility consisting of an **integrated switch-selector** inside the non-accessible metal-enclosure (tank); which associated to the switch-disconnector and earthing switch of the HV switchgear allows the simple and safe connection of the cable testing apparatus, by using the sequence of operations described in figure 5.

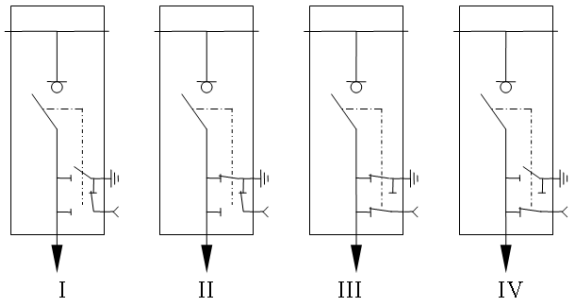

Figure 5– Sequence of operations for voltage injection

The integrated switch-selector has two positions:

Connected to earth: In-service position and when accessing the cable testing compartment, the access points to connect the voltage source for cable testing are earthed, so these points are not dielectrically stressed and are safe to be touched. ("I" & "II" in figure 5 and figure 6)

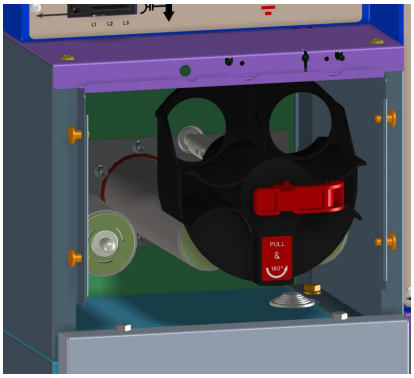

Figure 6 – Switch-selector in earth position

Connected to cables: In cable testing position ("III" & "IV" in figure 5 and figure 7), the access points are connected (internally in the tank) to the cable bushings.

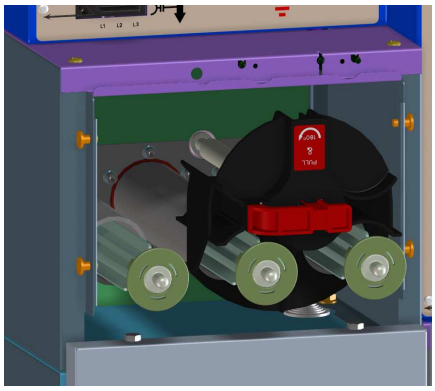

Figure 7 – Switch-selector in cable testing position

The switch-selector can only be manually operated from the cable testing facility compartment. The opening of this compartment is interlocked with the earthing switch position which has to be in the closed position to render access to it ("II" in figure 5).

Once the cable tests are done, it is not possible to close the door of the cable testing facility compartment if the switch-selector is in the position "connected to cables", and if this door is not closed, it is not possible to operate the switch-disconnector.

The points of access for voltage injection are prepared to connect a simple crocodile clip and to withstand the testing voltage without the necessity of supplementary means of isolation.

Comparison

The new proposal of cable testing facility described above is compared in table 2 against the four type of systems used for the same purpose summarised in table 1.

ATTRIBUTES / SYSTEMS	Type 1	Type 2	Type 3 (British)	Type 4 (French)	ORMAZABAL Solution
Grants original insulation condition of cable connections	NO	NO	YES	YES	YES
Grants original continuity condition of earthing system	YES	YES	NO	NO	YES
Requires access to the cable connections	YES	YES	NO	NO	NO
Points of voltage injection inside an interlocked compartment	YES	YES	YES	NO	YES
Necessity of specific tool to connect voltage source	YES	YES	YES	NO	NO
Necessity of tool to assemble-disassemble parts with torque	YES	YES	NO	YES	NO

Table 2 – Comparison of attributes per cable testing systems

CONCLUSIONS

A new available cable testing facility integrated into classical MV switchgear allows performance of cable tests without need of specific tools, adaptors nor additional isolating means, in a self-safe and reliable sequence, regardless of the specific knowledge of the involved persons on the particular switchgear. The cable testing facility is placed in a specific compartment interlocked with the earthing switch and the switch-disconnector. The chosen configuration allows the switchgear to be kept in the same condition as delivered and guaranteed by the manufacturer. The cables and connectors maintain the original condition as during commissioning.

REFERENCES

[1] IEC 60230 Impulse Tests on Cables and their Accessories.
[2] IEC 60229: Tests on cable oversheaths which have a special protective function and are applied by extrusion
[3] IEC 61442 Electric Cables – Test Methods for Accessories for Power Cables with Rated Voltages from 6 kV (Um=7,2 kV) up to 30 kV (Um=36 kV)
[4] IEEE 400: Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems
[5] IEEE 400.1: Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above With High Direct Current Voltage
[6] IEEE 400.2: Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)