ULTRA-SAFE AND RELIABLE M.V. G.I.S.
FOR PRIMARY SUBSTATIONS

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INTRODUCTION

The electrical network consists of a complex system where one of the most important points is the Primary Substation (HV/MV or MV/MV). They work as essential nodes of the system to transform the voltage, distribute and ensure the continuity of service. These goals are common not only for the utilities in their distribution networks but also for those primary substations involved in distributed generation (windmill plants, hydro power plants, etc.) and for MV users such us industries (petrochemical or mining plants) or large infrastructures such us airports or railways.

MV switchgears for primary substations should fulfil every electrical requirements offering at the same time the maximum safety level for operators, reliability (to ensure continuity of service) and minimum maintenance (reducing costs and avoiding power outages). It should integrate every parameter in the SCADA system to make the diagnosis of the switchgear and operate remotely if necessary.

This paper describes the most advanced Medium Voltage Gas Insulated Switchgear (G.I.S.) for Primary Substations. The architecture and design consider the latest experiences o f the utilities in this field whose main goal and purpose is to have a modern and safe MV switchgear that guarantees the maximum continuity of service.

EVOLUTION OF MV SWITCHGEAR IN PRIMARY ST

Historically, the most extended architecture of the MV switchgears for Primary Substations has been the classic metal-clad or metal-enclosed withdrawable panel. This arrangement was very useful in the past when the use of magnetic or oil circuit breakers needed periodic maintenance of the poles. This matter, joined with the fact of possible failures (oil leakage...) made interesting the circuit breaker withdrawable solution for MV panels, because it allowed to replace the damaged circuit breaker very quickly using the spare one existing in the substation. However, this architecture implies that the busbars and connections must be air – insulated. Therefore, it is compulsory to execute a periodic maintenance of this air – insulated parts (cleanness of busbar isolators, analysis of corrosion...) which are exposed to the atmospheric agents such us condensation (due to temperature cycles), humidity, dust or salt. The revision of these parts implies the loss of continuity service.

Nowadays the new alloys in Material Engineering which have eliminated the "chop current" effect [1] and the advanced industrial processes have led vacuum to be the most employed technology in MV circuit breakers [2]. In fact, due to modern manufacture process and vacuum insulation techniques, the new revision of IEC will even report that it is not necessary any maintenance for a vacuum tube as it is considered to have a zero leakage rate during its life [3].

Thus, thanks to the absence of maintenance of the living parts that avoids technical power outages, the continuity of service increases, which is essential in a Primary Substation. This reason, added to the compactness and safety of GIS switchgear, has displaced the air insulated withdrawable panel out of Primary Substations. Nevertheless, AIS remains interesting for special industrial arrangement such as double fuse contactor panels and very high busbar nominal currents.

RELIABILITY AND CONTINUITY OF SERVICE

The main characteristic of this switchgear is the fully insulation of every living parts. It means that the ambient conditions such as dust or condensation do not affect any of the active parts of the panel. It increases at maximum the continuity of service and avoids the need of programmed power outages to perform the maintenance. The complete insulation of all the MV elements increases the reliability compared to the air – insulated withdrawable cubicles that need programmed maintenance.

The new switchgear is completely modular and it has avoided block designs (several functions inside a common gas tank) because missing one function due to an internal arc would imply to miss the complete block (extending the fault and producing a larger loss of continuity service). The main advantages of this modular design are the following ones:

1. It permits to extend or replace a complete panel without gas handling at site. This was consider as an essential condition to avoid changing the nominal properties of the dielectric gas tested at factory (pressure, risk of contamination due to humidity...) and minimising the operation time at site.

2. Removing one central cubicle do not need the displacement of the adjacent panels. It minimises the time of replacement and thus the time of the outage and avoids moving the MV cables of the adjacent cubicles, which is always hard due to the number of cables per phase, weight and curvature radio.

Last but not least, the fully insulation of every active parts also reduces at minimum the space requirements which saves costs of the civil building and reduce the area of the ST. This is especially interesting for those Primary Substations placed in the town centre where the availability of the space and its price is a critic point (36 kV underground stations...)

Vacuum circuit breaker

The circuit breaker, which is fixed type, is a vacuum technology breaker with no need of maintenance of the contacts or any living parts during the life of the switchgear. This circuit breaker has been even type tested under the most critic conditions:

36 kV Back to back capacitor bank type test. This new switchgear includes a vacuum circuit breaker that has been tested according to the latest IEC 62271-100. As the compensation of the power factor in the medium voltage network is a clear tendency, the switchgear has even satisfactorily passed the 36 kV three phase back – to – back capacitor bank tests according to the hardest requirements of the Spanish utility ENDESA:

Switching of two back to back capacitor banks, Vn=30kV, C=6 MVAr, Limitation Inductance = 25mH and 75mH respectively for each capacitor bank, Scc=1.300 MVA.

It implied to perform the sequence indicated in the standard reference IEC 62271-100 for these parameters:

- Inrush Current (2nd capacitor bank): 7,98 kA
- High frequency in the connection: 4.886 Hz

TABLE 1: "Back to back capacitor bank: parameters of the type test"

Operation		CO		
Phase		R	S	T
Applied voltage, phase value	kV	16,9	16,8	16,9
Inrush current, peak	kA	12,9	14,7	9,10
Breaking current, phase value	A	122	123	123
TRV, peak	kV	54,5	48,3	-46,1

TABLE 2: "TRV in the 36kV back to back capacitor bank test"

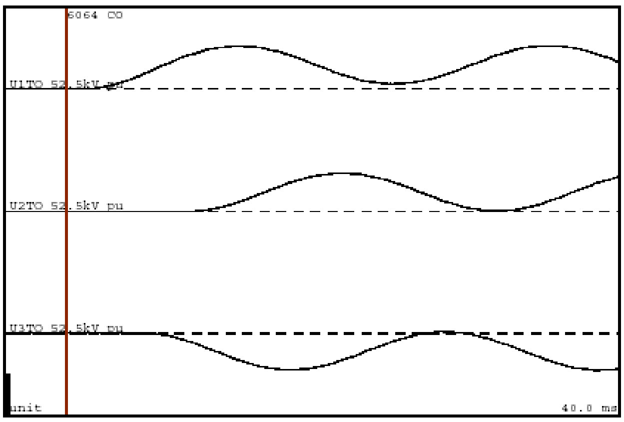
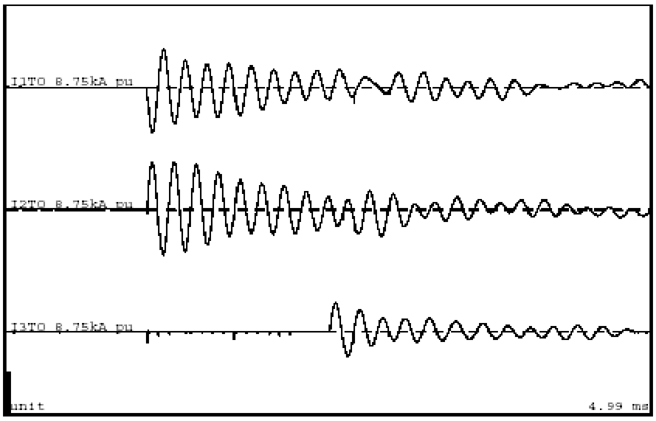


TABLE 3: "In-rush current in the 36 kV back to back capacitor bank test"



Electrical endurance type test. To ensure the high capability and endurance of the circuit breaker it was tested 100 operations at full rated short circuit current.

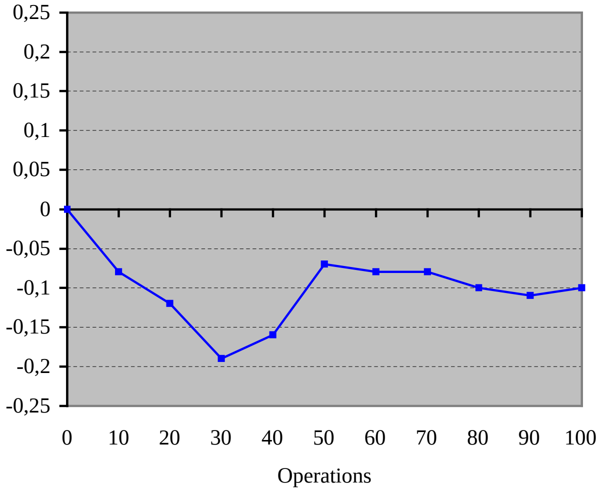
Table 4 shows the equivalence of the complete sequence described in the IEC 62271-100 for each test duty (T10, T30, T60 and T100s) and the result shows that the type test passed by the breaker is 4 times more critic than the type test stated by the IEC.

TABLE 4: "Electrical Endurance Comparative"

Current	Current	Operating Cycle	Equivalence of each operating cycle to 1 test at Rated Isc	Number of openings per TABLE 21 of IEC 62271-100 List 1	Equivalent tests at Rated Isc
Per unit of Rated	Symmetry		Erosion is an inverse Square function of current		
0,1	symmetrical	O O-0,3s-CO O-0,3s-CO-t-CO	0,01 0,02 0,03	84 14 6	0,84 0,28 0,18
0,3	symmetrical	O O-0,3s-CO O-0,3s-CO-t-CO	0,09 0,18 0,27	84 14 6	7,56 2,52 1,62
0,6	symmetrical	O O-0,3s-CO-t-CO	0,36 1,08	2 2	0,72 2,16
1	symmetrical	O-0,3s-CO-t-CO	3,00	2	6,00
Equivalent interruptions at 100% Rated Isc					22

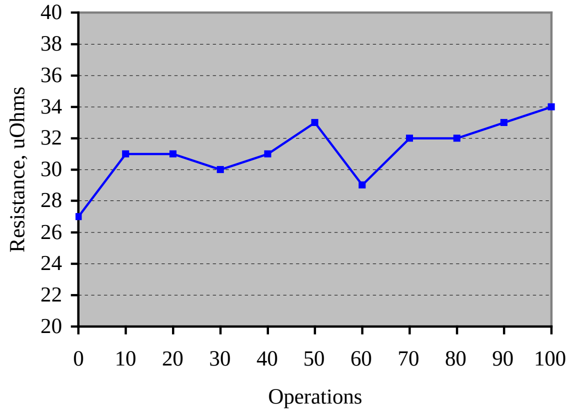
The table number 5 indicates the evolution of the erosion of the contacts along the 100 full short circuit current operations. This test proves the longer electrical life of this vacuum circuit breaker compared to other breaking technologies.

TABLE 5: "Erosion vs. operations 25 kA rms on 2.79" Axial Magnetic Contacts"



The previous graphic clearly shows how the contacts of the vacuum circuit breaker have a «self – condition» process along the successive opening operations. This is one of the main characteristics of this technology that permits to extend the life of the switchgear compared to others where contacts and the dielectric gas used to extinguish the arc degenerate with each opening process. The table 6 shows that the resistance of the poles of this vacuum breaker hardly increases after 100 breaking operations [4].

TABLE 6: "Total pole resistance vs. Operations 25 kA rms on 2.79" Axial Magnetic Contacts"



After having proved the high electrical endurance of the vacuum tube, the circuit breaker mechanism was also mechanically tested, getting the M2 class (10.000 operations) according to IEC 62271-100.

Measurement

This switchgear allows the installation of classic inductive voltage and current transformers. They will be always placed outside the gas tank so that the replacement of any of them is easy and, what is more important, the failure of these elements will not affect the functionality of the panel.

Voltage transformers. The voltage transformers are always placed out of the gas tank so that a hypothetical failure and explosion of one VT (overvoltage, ferrorresonance...) does not affect the main gas chamber. As the functional unit is not damaged it allows to increase the continuity of service. The voltage transformers are plug– in – type maintaining the fully insulation philosophy of the switchgear.

Current transformers. These are ring type current transformers that are placed around the outer cone type bushings of the cubicle. This disposition makes easy the installation of the current transformer (avoiding the installation in the cable trench), and it eliminates possible mistakes during the mounting process (earthing braid).

SAFETY

Primary Substations are the main heads of the electrical distribution. These are the closest points to the transport network and the short circuit current that the primary switchgear have to withstand is usually higher than those installed in the secondary distribution as the short circuit current decreases due to the impedance of the net.

Thus, every compartments of the switchgear have been internal arc tested according to the latest IEC 62271-200 at the maximum rated short circuit current during 1 second. The busbars, gas tank and cable compartments have fulfilled the 5 requirements stated in the annex A of the standard.

The design of this new switchgear has been made so that it is not possible that any three – phase internal arc occurs. To achieve this, metallic plates have been included in the cable compartment and in the busbar compartment, providing an extra metal-clad protection between the phases.

FIGURE 1: "Switchgear after internal arc tests at 36 kV/25 kA/1s"

Another elements related to the safety of the operators and the network itself are included, such us the motor operated disconnector with reliable indicating device (IEC 62271-102), tough interlockings, and a positive voltage presence-absence indicator according to IEC 61243-5. The making duty is also transferred to the circuit breaker to increase safety to operators and equipment itself.

INSTALLATION AND OPERATION

MV and LV connections

The outer cone type bushing has been selected for the MV cable connection. This type of bushings requires standard T shielded connectors that are commonly used for the secondary distribution switchgear. The process of making the MV cable is easy and well known by the operators. Besides, these outer cones have been installed at a minimum height of 650 mm from the floor so that it helps the arrival of the cables and minimises the depth of the cable trench of the building, saving costs in the excavation works.

The switchgear includes also specific channels for the supply and control low voltage cables. These channels are placed on the top of the low voltage compartment and both sides of the cable compartment. In this way the panel is flexible to admit the entering of the control cables from the bottom or from the top providing fully flexibility according to the civil project of the Primary Substation.

The low voltage compartment also includes a plug – in connector system that makes easy the connection between the operation and control free contacts of the panel and the low voltage terminal blocks installed in the LV compartment. It reduces the time of the installation of this compartment at site and fully eliminates the wiring mistakes.

Control

Every signals of the switchgear (including state and commands for the circuit breaker and disconnector, earthing switch, gas level, current and voltage measures, etc.) are integrated in the multifunction protection and control system to get a complete centralised operation. It allows to operate remotely to re-arrange the configuration of the substation if necessary in the minimum time.

The switchgear allows the installation of whatever of multifunction protection and control system and even considers the possibility of the installation in the front cover of the panel. It makes easy the access to the frontal communication port of the relay and display.

FIGURE 2: "Detail of the control compartment"

Routine tests at factory

The actual tendency of the market, which demands complete and fully tested equipment to be directly installed in the network, implies that the supplier must guarantee the complete functionality of the entire switchgear.

That is why the complete protection scheme, including current measurement system, wiring, multifunction relay, opening coils, etc. is completely routine tested at factory avoiding additional wiring to external RTUs which reduces the manual operation, saving costs and mistakes at site.

Finally, to ensure the long life of the insulation, the partial discharge test is done as a routine test in the factory.

CONCLUSIONS

The latest black – outs happened in some regions of Spain, and the penalties that the utilities have had to face, have forced the continuity of service to be the main goal for the utilities. The switchgears for the Primary distribution network must contribute to this purpose with a design that must avoid periodical maintenance of the living parts, offering the maximum safety and reliability at the same time.

The MV Gas Insulated Switchgear introduced in this paper, plug & connect philosophy, integrally designed for application in MV Substations, fulfils the highest requirements for the reliable, safe and modern operation of primary stations.

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