IMPACT OF MEDIUM VOLTAGE SWITCHGEAR TECHNOLOGY ON OPERATING MODES IN THE NETWORK

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ABSTRACT

The metal enclosed switchgear suitable for installation in MV / LV public distribution substations or private customer substations are key elements to ensure continuity of service in electricity supply. For that purpose, MV equipment shall comply with the requirements for insensitivity to harsh ambient environmental conditions found in the field. Based on modern technologies, new architectures of MV switchgear are able to meet these high requirements. Adapted operating modes allow to fulfill all usual expected functionalities duri ng operational life on site.

INTRODUCTION

To better meet the requirements on harsh environmental conditions withstand, the market is moving from a technology type AIS (Air Insulated Switchgear) or SIS (Solid Insulation System) to GIS with metallic enclosures (Gas Insulated Switchgear) or 2SIS (Shielded Solid Insulated Switchgear). The new solutions used for this purpose involve consequences for operation modes and therefore on single-line diagrams. The evolution of product architecture leads to a simplification of operating procedures, improving reliability and safety.

However some current standards or specifications are not yet able to properly cover some architectural configurations of GIS or 2SIS type and should be reconsidered. For example, for substations including MV metering, the presence of an upstream disconnector on the metering unit makes the integration of products based on these technologies very complex to satisfy all the customer requirements.

In a first part will be explained how architectures of MV switchgear may be simplified. For these architectures, key success factors will be described. As a consequence, the reduced dimensions of typical switchboards will be presented. In a last part will be explained how these architectures facilitate the smartgrid deployment.

SIMPLIFIED ARCHITECTURE BASED ON NEW TECHNOLOGIES

Focussing on the usual functionalities, a target of the use of modern technologies is to simplify the architectures.

Which technology for harsh environment in secondary applications?

Taking advantage of the reference experience of **AIS (Air Insulated Switchgear),** modular, versatile, with wide and comprehensive offers, the **GIS (Gas Insulated switchgear**), compact solution for Utilities MV distribution bring solutions ready-to-connect, insensitive to harsh environments or bad conditions of installation, with minimum maintenance, extensible for network evolution. These equipment are fitted with fixed CBs and separate disconnection.
The screened plug-in or bolted type cable separate cable connectors ensure high degree of insensitivity to the environment.

Simplification of single line diagrams and operational modes

Insensitivity to harsh environment allows to use combined functions, such as switch-disconnectors and circuit-breakers-disconnectors replacing separated components for more compactness.
By comparison with AIS technology it's no more necessary to get specific features (such as sliding contacts, for example) to carry out operating maintenance.
For secondary distribution applications, on some GIS products, the main device is an SF6 disconnecting Load-Break Switch or Circuit-Breaker allowing for a very simple three position diagram. Breaking and disconnection are performed in a single operation, leading to the three-position scheme (line, open and disconnected, earthed). Interlocking safety is inherent between the different positions. Cable testing device allows access to cable without opening the cable box nor interfering with the cable termination.

Migration of withdrawable CBs towards fixed CBs and the use of vacuum breaking, modern highly reliable CBs was a key factor for the acceptance of fixed CBs.
The modular architecture of **SIS or 2SIS (Shielded Solid Insulation System)** is developed in this respect**.** Proposed arrangement including an upstream vacuum disconnector load-break switch or Circuit-Breaker and a downstream earthing switch provide an additional gap isolation between cables and bus-bars. All previous advantages are kept with the real three positions scheme [1].

The same functional system approach as shown in Figure 1 is also applied for all other functions: metering, switching, breaking, riser, or embedded metering solution.

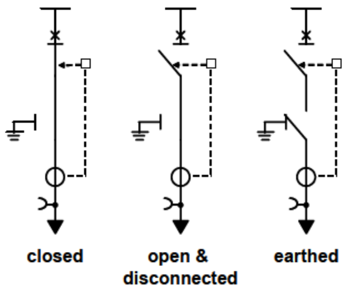

Figure 1.: Modular architecture 3 position single line diagram with shielded solid insulation switchgear (2SIS)

The **GIS and 2SIS** offer modular, harsh environment robust, safe, simple, smart solutions. The functional units are based on functional bricks such as switching device, cable test device, top connections, bottom connections, bottom compartments.
These technologies combine modular switchgear, customer oriented offer structure, easy to install.

These GIS or 2SIS type of simplified architecture are ideally suited for installation of LV ring type current transformers. The layout of MV panel is reduced. The dimensions of power distribution substations are reduced. These technologies permit to install cables earthing switch inside the core product reducing the footprint of switchgear. The metering substations are simplified.
Utilities generally accept the position of these LV ring CTs downstream the cables earthing switch. Different diagrams are available on the market for this purpose.
Compared to GIS RMUs, the 2SIS technology associated with a new three positions diagram arrangement [Figure 1] offers much better modularity.

KEY SUCCESS FACTORS ARE AVAILABLE

Some key features, essential in terms of design and functionalities of sensors, test boxes and cable testing devices make possible to take benefit of the new architectures while satisfying all operational requirements.

Sensors

For smart grid deployment, it will be necessary to increase the number of sensors in the networks. For that purpose, new generations of sensors, smaller size, less consuming are now available [2] and [3].
For current measurements, a new generation of current sensors, the LPCT technology (Low Power Current Transformer) has been launched in 2002. It is compliant with international standard IEC 60044-8 [4] and the major MV switchgear manufacturers have widely adopted it. The LPCT consists of a current transformer having a small core secondary winding connected to a integrate shunt resistor. The shunt resistor converts the secondary current output into a low voltage signal.
The same trend is observed for VTs. 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.
In recent years the development of insulating materials and the improvement of industrial processes resulted in an increase of the quality of voltage transformers and, as a consequence, an increase of service operation of the products.
New shielded and insulated solutions are now available for voltage transformers ensuring the most efficient withstand to harsh environment because the insulating performances are not affected by any possible electrical field variation. Then, these types of VTs become totally insensitive to harsh environmental conditions (dust, pollution, humidity, temperature changes, etc ...), as more and more required by utilities.
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 single earthfault currents. These low magnitudes of single earthfault currents make the choice of the rating of MV fuses very delicate.
Comparing the risks, some DNOs in different countries already have chosen to use VTs without MV fuses.

Test box

In the past, periodic control protections were due to the fact that settings of former electro-mechanical relays were subject to drifts over time.
Today, periodic inspections aim to verify the whole protection chain: ring CT + protection relay + coils and circuit-breaker tripping. For this purpose, a test fault current or an image of it shall be injected in the main circuit. This control is called **Primary Injection**.
The replacement of fuses functions by circuit-breakers for protection allows the customer to get an effective and reliable protection chain including all parts of the functional triggering chain.
The safety aspect of triggers on equipment with the ability to test the trigger without changing the relay settings is a major advantage of such solution.
The primary injection allows periodic monitoring of the protection chain by injecting a primary current with a current source without removing cables or other functions of MV switchgear and without accessing to MV compartments. Figure 2 shows a typical connection diagram based on primary injection test.

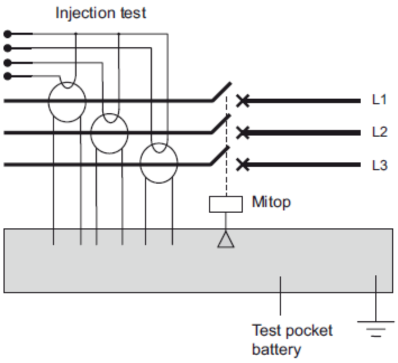

Figure 2. Primary injection test connection diagram.

The principle and concept uses specific relay with sensors, CT and LPCT.
For this purpose, an additional primary injection test circuit is permanently installed in the cubicle, through the ring CTs. Therefore, it is possible to test the integrity of the whole protection chain, including CTs. Figure 3 shows a typical arrangement of a permanent primary injection circuit.

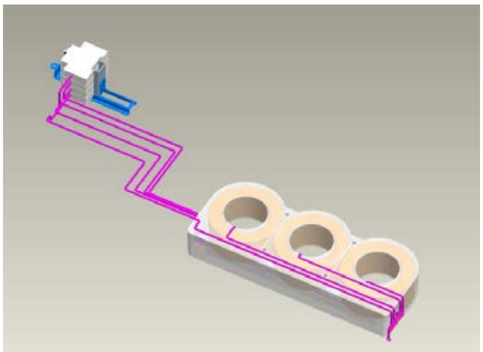

Figure 3. Permanent primary injection circuit.

The test circuit is adapted to the protection relay testing input. For these kind of relays having temporary testing position, typical 50A magnitude of injection current is adequate, without changing the settings.
The primary injection testing circuit integrated in the cubicle also includes a LV circuit-breaker protection where the test box shall be connected.

This solution covers all client features, with the objective to offer a system without dismantling of MV cables, providing a connection to the client to connect the injection source and maintaining MV loop voltage (bus-bar energized).

As a consequence, the evolution of product architecture leads to a simplification of operating procedures, improving reliability and safety because of lower need to access MV compartments.

Cable testing dedicated device

Particular attention is given to cable testing facilities. MV cables of the distribution network are installed for much longer time than switchgear. As these MV cables are becoming very old, there is a clear trend for an increasing need of cable testing to detect any sign of distress.
This fact has been taken in account in the IEC standard 62271-200 Edition 2.0 [5]. This edition now includes new ratings for cable test voltages. Rated power-frequency cable test voltage and rated d.c. cable test voltage are defined because tests may be carried out with a.c. or d.c. injection.
To make these numerous cable test operations easy, it is of great importance to rely on clear and simple procedures.
There are different possibilities for cable testing:

- Through cable plugs
- Through earth collector bolted bar
- Through safely and fully interlocked system: enhanced « automatic star-point »

In GIS or 2SIS switchboards, dedicated cable test devices integrated to the cubicle offer the highest simplicity, because it is possible to test the cables without disconnecting them and even without directly accessing them.

DIMENSIONS OF POWER DISTRIBUTION SUBSTATIONS ARE REDUCED

The new GIS or 2SIS technologies allow solutions involving evolution for operation modes and therefore on single-line diagrams.
The layout of power distribution substations is reduced.
For example, in the case of complex metering substations, the comparison of typical traditional AIS layout with GIS demonstrates this optimization. Figure 4 shows an example of a switchboard.

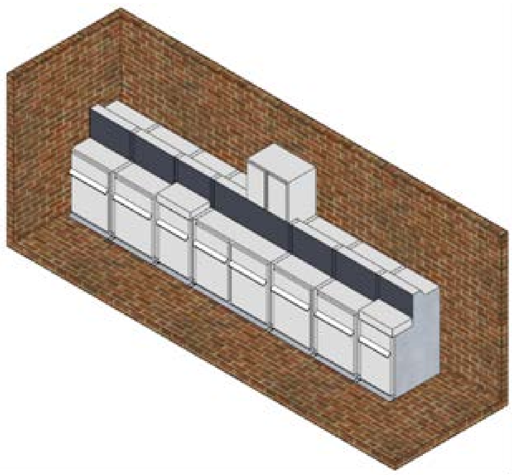

Figure 4. Layout of full GIS metering substation.

It includes ring loop functions with two CBs belonging to the distribution network, voltage metering, current metering and downstream disconnector, 2 CBs and 1 fuse-LBS for private network.
Illustrated by the single line diagram of Figure 5, the dimensions of such a switchboard may be in the range of: length 4.5m, depth 0.7m and heigth 1.6m including LV cabinet.

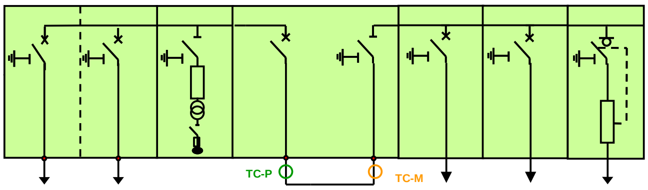

Figure 5. Single line diagram of full GIS metering substation.

All CBs and LBs provide disconnection function, allowing to satisfy all operating modes. No separate upstream disconnector on the metering unit is needed. The Voltage transformers totally insensitive to harsh environmental conditions are installed without the use of associated medium voltage fuses. The cable earthing switch is integrated inside the core product. The LV ring CTs are installed downstream the cable earthing switches**.**
In these conditions, the height, the width and the depth of the GIS switchgear are lower than those of AIS architecture. The surface saved is over 35%.

SMARTGRID DEPLOYMENT IS FACILITATED

The Smart Grid deployment, as a tool to support energy efficiency and energy availability, more and more relies on technologies insensitive to harsh ambient environmental conditions and on an extensive use of remote-control systems. The GIS and 2SIS architectures of switchgear bring a real optimization of functions, that should be reflected by some changes in specifications, in line with the proposed single line diagrams.

This type of simplified architecture is also ideally suited for installation of LV ring type current transformers. The metering substations are simplified. The verification of the insulation of MV cables is possible by dedicated reliable testing devices integrated in the switchgear, without the need to disconnect them.

Technologies insensitive to harsh environments such as GIS and 2SIS are compatible with all functional requirements met in network operations while reducing the needs to access to components in compartments.

CONCLUSION

These new technologies that bring a high level of insensitivity to harsh environment and provide high reliability product and personnel safety, have now to be considered in specifications and standard revisions.
Technological developments from the AIS (withdrawable or fixed) to GIS or 2SIS lead to smooth the boundaries between primary and secondary.
Modular ranges based on compact vacuum switches and circuit breakers, metering units with shielded solid insulation, can provide high protection & all control functionalities.
LV ring type current transformers integration on Medium Voltage switchgears allows a simplified architecture.
Vacuum switch-disconnector and vacuum circuit breaker disconnector with integral earthing permit to create innovative single line diagrams [Figure 1] using vacuum disconnection.
These new technologies are able to offer:

- high operator safety with lower probability of internal arc fault and less consequences
- intuitive operation thanks to the well known and appreciated 3 position diagram
- interlocked cable test dedicated device operated from the front
- reduced maintenance
- high flexibility and modularity (front cabling, modular relay cabinet).

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