INTRODUCTION

The new standard IEC 62271–200 concerning Medium-voltage metal-enclosed switchgear and controlgear introduces a concept of internal arc performance class IAC. It recommends a risk evaluation characterising the material as negligible or relevant risk level for the operator and the general public. Nevertheless, no reference is made in this standard to the pressure applied on the building nor to the consequences that could have an indirect effect on persons. This is taken into account by the standard IEC 61330 for prefabricated substations. No equivalent standard exists for substations inside buildings of general purpose. When the substation is located in a building: there is no way to make a full-scale test to investigate how the local conditions will affect the whole system behaviour. As a matter of fact, such a test cannot be considered because of non-repetitive surroundings.

Value of internal arc currents to be taken into account

We require a right approach of needs regarding internal arc resistance of metal-enclosed MV switchgears. We therefore calculated, which short-circuit currents may appear in the Belgian network. These calculations are taking into account the impedance of the various MV networks as well as the short circuit power of the HV networks.

On HV/MV substation busbar, the short circuit current can typically reach a value of about 18 kA, and exceptionally 25 kA. That is the reason why the internal arc performance of the MV switchgear in HV/MV substation has to be 25 kA –1s. When we are at a minimum distance of 500 m of these substations, the typical short circuit current decreases to 14 kA –1s if a single cable link is concerned. This is the case for most of our MV/LV distribution substations. As for important “dispersion” MV-substations, the retain value is 16 kA-1s, because often fed by means of two parallel cables coming directly from the HV/MV substation.

These short circuit current values concern arc fault between phases. A short circuit from phase to ground is limited to 2 kA by an impedance link between neutral and ground.

PROPOSED SOLUTION

Application in building of general purpose

In big cities, it is very hard and expensive to find free ground to build stand-alone distribution substations. In most cases, the MV distribution substations usually have to be enclosed inside general purpose buildings (apartment, shops or offices).

Starting from internal fault tests results realised in stand alone « kiosque» substations and from a modelisation by cooperating with RWTH-Aachen University (results published in the CIRED conference 2001), the simulations were applied to the most classical situations met in general purpose buildings. From this study, Laborelec and Electrabel have extracted a rooms classification transposable to the real situations according to the aptitude of equipping them with a well defined type of MV equipment.

The compatibility between rooms and MV switchgears is given in the following table:

To make this classification usable, it is necessary to establish a corresponding MV-equipment classification.
**Type of room**
- Room without specific mechanical resistance.
- Room with a limited pressure resistance (impact of the volume greatly affects the required resistance.)
- Switching room with secondary room for pressure relief and exhaust opening to a neighbouring room.
- Switching room with secondary room for pressure relief and direct opening to the outside, or very large room.

**Requirements on MV-metal enclosed switchgear regarding internal arc effect.**
- Metal-enclosed switchgear either with negligible risk, or equipped with a pressure relief channel to the outside.
- Metal-enclosed switchgear equipped with an arc eliminator.
- Metal-enclosed switchgear with pressure relief flaps and arc eliminator.
- Metal-enclosed switchgear with pressure relief flaps.

**MV METAL-ENCLOSED SWITCHGEAR : INTERNAL ARC CLASSIFICATION**

We can divide these MV metal enclosed switchgears in two families:
- On the one hand, the categories for which the risk can be considered negligible in the sense of standard IEC 62271-200. Metal-enclosed switchgear IAC (internal arc classification) classified is not necessary. These categories receive references AA10 and AA20 (detailed below).
- On the other hand, the categories for which the risk is considered to be relevant. Only metal-enclosed switchgear and controlgear IAC classified should be used. These categories receive references AA31 to AA34 and AA40.

**AA10 - Metal-enclosed switchgear with a minimised risk level.**

Conception of the insulation system is made to insure that one insulation defect cannot lead to an internal arc between phases or it will give an alarm or execute an action to prevent such an internal arc. The arc current shall be avoided or reduced to maximal 2 kA (phase-ground fault) or to a few kA by limiting the let-through current and fault duration.

Practically, these systems are realized with RMU (Ring Main Unit with all active parts in a SF6 filled cubicle) with controlled presence of insulation gas, with earthed screens between phases, with metering cubicles protected by fuse-switch combinations.

**AA20 - Metal-enclosed switchgear without any external consequences in case of internal arc fault.**

All the active parts of the system are disposed in an airtight cubicle. A fast elimination of arc is obtained before having any external consequences (flames, hot gases, pressure) by diverting it to metallic short circuit by means of fast-sensing and fast-closing devices (arc eliminator). The cubicle has to remain airtight after occurrence of the internal arc.

**AA3x - Metal-enclosed switchgear with limitation of the external consequences (with direct evacuation of hot gases).**

These categories are representing the metal-enclosed switchgear IAC classified with defined accessibility. These equipments are built to offer a protection to persons in the vicinity of the equipment in normal operating conditions in the event of internal arc. The level of protection does not ensure the safety of person due to non-adaptation of the building to the induced pressure. When such equipment is used, special requirements have to be taken concerning the room: improvement of resistance of walls and door and/or enlargement of cross section of exhaust openings. It goes without saying that these switchgear categories have to be tested minimum for an IAC 14kA-1s AFL (Accessibility A: restricted to authorized personnel only; F for Front side; L for Lateral side)

These categories are divided into 4 types:
- **AA31 - Metal-enclosed switchgear with pressure relief flaps.**
- **AA32 - Metal-enclosed switchgear with pressure relief flaps and arc eliminator.**
- **AA33 - Metal-enclosed switchgear with pressure relief channel to the open air.**

The same type as the previous one but equipped with an arc eliminator, which diverts it to metallic short circuit by means of fast-sensing and fast-closing devices. The necessary short closing time depends on the volume of the room considered.

**AA34 - Metal-enclosed switchgear with pressure relief flaps.**

The same type as AA31 but equipped with a pressure relief channel. The only requirement is an exhaust opening for this channel. Danger for anyone outside the substation has to be avoided.
AA34 - Combination of AA32 and AA33.

The same type as the previous one but equipped with an arc eliminator.

On the field, two cases can be met. The designer can enforce his requirements to the architect of the building for the design of the substation room with a view to the equipment he wants to install. But most of the time, the building is already erected and he only has a limited impact on minor modifications as enlarging of the ventilation openings. This is also the case when a refit of MV electrical installation is foreseen. Concerning the necessary electrical functional units, available volumes and adaptation possibilities, it can be interesting to use a MV metal-enclosed switchgear equipped with an arc eliminator, which diverts the electrical arc to metallic short circuit by means of fast-sensing and fast-closing devices. (e.g. one of the solution indicated in the standard EN 62271-200). This technique enables to avoid long reaction time before eliminating the arc. It cannot be obtained in case of classical solutions, due to reaction of electronic switch systems detection, protection relays, signal transmission and of circuit breaker break time. The firm DEBA with a particularly rapid arc eliminator system proposes such a solution. The effects of a 14 kA internal arc in the cable compartment extinguished by this system was simulated by RWTH Aachen University with a specific program, and it demonstrated that, for an average room, the use of this device may reduce the pressure reached in the room to an acceptable value of wall resistance.

Herebelow, an example of pressure rise simulation for a 14 kA internal arc fault, when the substation room volume is 20 m³ (pressure in blue), the neighbouring room 100 m³ (pressure in red), the cross section of the relief opening between both rooms is 0.5 m². The black line gives the maximal pressure if the arc eliminator works within 48 ms.

In order to reach acceptable pressure in such a small substation volume for classical wall resistances, it is necessary to increase the relief opening to about 1m². If it is possible to dispose of a larger substation room, the pressure will decrease rapidly and the effect of an arc eliminator becomes especially interesting because the pressure is rising slower.

In the example below, for a large substation room of 500 m³, one can see the influence of the relief opening cross section from the substation room to the open air.

<table>
<thead>
<tr>
<th>Overpressure simulation in small substation room</th>
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<tbody>
<tr>
<td>Overpressure in room A [mbar]</td>
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<tr>
<td>time [s]</td>
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To determine the exact pressure reached in a given substation equipped with a well-defined metal-enclosed switchgear, it is necessary to know all the parameters such as dimension of pressure relief flaps, effective opening of the substation ventilation grid etc…

**Compatibility between transformers, transformer protection and room resistance**

As shown above, the effect of an internal arc in the metal-enclosed switchgear is taken into account to determine the type of room that can be used. One has to make sure that the transformer is not going to be the weak point of the assembly.

In the case of use of oil filled transformer, the event to prevent is the occurrence of leakages and the explosion of the tank. In the paper in reference [1], it was demonstrated that a protection by means of fuse-switch combinations limit the let-through current to few kA and the fault duration to few ms. This protection has to be completed by a pressure detection which only opens the switch of the fuse-switch combination.

In the case of a dry transformer, the prevention of a short circuit and an electrical arc is much more difficult to insure. That is why it is recommended to place it in an “AA31” type cubicle if the substation room has the required mechanical resistance, or in a separated reinforced room.
CONCLUSIONS

The new standard IEC 62271–200 concerning MV metal-enclosed switchgear and controlgear introduces a concept of internal arc performance classes IAC. No reference is made in this standard to the overpressure in the building nor to the consequences that could have an indirect effect on persons. This type of effect is taken into account by the standard IEC 61330 for prefabricated substations. No equivalent standard exists for substations included in buildings of general purpose.

The Belgian Distribution Network Organisations enforce requirements concerning compatibility between categories of metal-enclosed switchgear and types of rooms inside city buildings, in order to ensure safety of persons and equipment. These requirements are based on calculations of pressures reached after the occurrence of an internal arc fault.

REFERENCES