# MITIGATE ARC EFFECTS WITHIN AN E-HOUSE

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## *ABSTRACT*

*This paper illustrates how the simulation can be used to assess the internal arc performance of an E-house. This one can be difficult to define for the engineer. Often, the Switchgear is classified as per the IEC 62271-200; but during the test, the pressure rise of the room (represented by two walls only) can't be measured.*
*This point is essential in an E-House which has a compact installation, and should be assessed beyond the standard; while the possibility to test the entire e-House is out of reach for economical reasons.*
*The article shows simulated pressure results, in relation with E-houses structural basic technologies. The impact of absorber technologies, as well as protection system, is demonstrated.*

## INTRODUCTION

When an arc occurs within a medium voltage metal enclosed switchgear, it produces a large quantity of hot gases. Such an accident is rare and can be caused by different causes, from miss-operation to equipment failure, or a combination of both. The IEC 62271-200 standard [1] propose an internal arc classification, defining a type-test to validate rated performance of a switchgear. This type test aims to check especially the medium voltage enclosure tightness to the hot gases, as well as the effectiveness of the gas evacuation system. If the gases are relived in the switching room however, their impact is only partially addressed, as only two walls are simulated. The pressure rise within the room is then never recorded.

Gases evacuation systems often are made of ducts, evacuating the gases outside the switching room. Such an arrangement prevents the relief of gases within the switching room; however, at the duct exhausts, flames are expected in case of arc event. Such an arrangement is then not suitable to meet fire, blast and IECEx protection requirements. E-Houses designed to meet these requirement are then made without any possible release of hot gases outside the building, but still may be fitted with overpressure vents for internal overpressure greater than 1.5kPa.
Such E-House's shall then be designed to withstand the pressure rise caused by the hot gases released within the room volume in case of internal arc. As the arc is continuously vaporizing solid raw material around itself, and there is no venting at all, the pressure rises until it is extinguished. The level of pressure reach in the room is linked to the arc duration, and therefore the effectiveness of the protection system.

In order to mitigate the effects of the hot gases in the room, dedicated passive devices, so-called "absorbers", have been introduced [2]. They constitute an obstacle to the flow, thus slow-down gas speed; and absorb partly the gas energy. One technology of absorber is commercially available associated with primary Air Insulated Switchgear, successfully type-tested. It implies a ceiling height of 4m minimum.

In this paper, a new generation of absorber is presented, in the objective to save some height.

## PRESENTATION OF THE E-HOUSE STUDIED AS AN EXAMPLE

### <u>Layout</u>

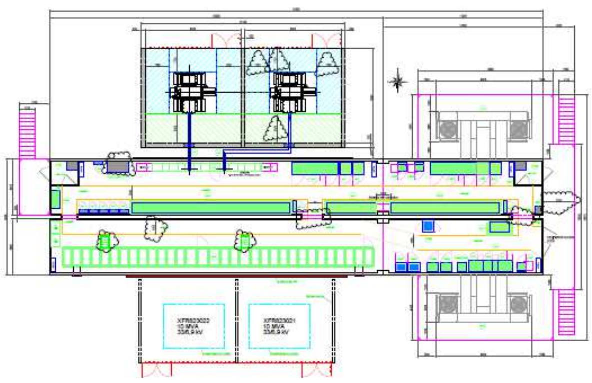

Fig. 1 E-House layout including neighborhood

The dimensions are: 34m (length) x 8m (width) x 4m (height).

The E-House has two rooms (MV/LV). There are three free openings between the two rooms.
The medium voltage switchgear has a total length of 21,5m. The two incomers are in the middle of the panel. The rated short-circuit currant is 31,5kA.

In the original design, the gases evacuation system is made of a collecting duct, venting gases to the outside. For the purpose of this article, this is changed to an exhaust within the switching room through one absorber, located on the top of the collecting duct, above the incomer cell (figure 2) This is a type-tested arrangement for this switchgear range.

Fig. 2 : view of a standard absorber on the gas duct top

## PRESENTATION OF THE INTERNAL ARC SIMULATION METHODOLOGY

### CFD basics

The methodology used in this paper has been described in several papers [3], [4]. It is based on Computational Fluid Dynamics (CFD) software – see [5] to check how CFD is applied in internal arc studies.

It implies a 3D model of all air volumes, the switchgear compartments, the collecting gas duct, and the switching room. Pressure field is then spatially-defined, and can be post-processed at any time during the event.

An arc fault is simulated within the breaker compartment of the incomer cell, just below the absorber. This is the most severe fault location, the arc being close to the switchgear vent.

The pressure is post-processed on 16m² surfaces, located respectively on the ceiling straight above the absorber, on the side wall aside the absorber, and on the end wall of the E-House (figure 3).

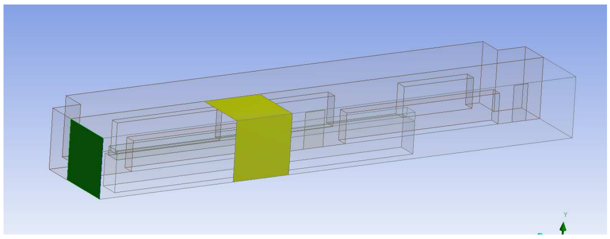

Fig. 3 : 16m² areas defined for pressure post-processing

### 31,5kA – 1s arc fault : results (reference)

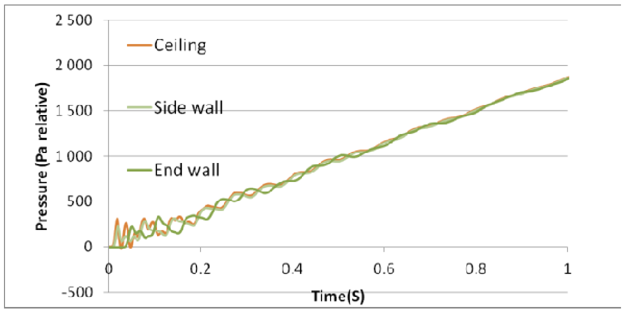


Fig. 4 : space-averaged pressure on given surfaces.

## DEDICATED ARC FLASH DETECTION SYSTEM APPROACH

This section describes the operating principles of a certain existing state-of-the-art arc-flash protection system. Most likely other systems also operate under similar principles. Although the basic functionality is fairly simple, the complete arc protection system consists of several components. One of the key ideas is to provide selective protection by dividing the installations into protection individual sections which are referred as zones. Figure 9 presents a scheme of a rather complicated setup with different parts of the installation marked as different protection zones. The arc protection system mainly consists out of the following four different types of components:

- Sensors (light or current)
- I/O units
- Central units
- Communication cables

In addition, the system naturally needs for example battery-backed auxiliary power supply system and other components; these however are not that relevant in this context and have been left out for the sake of simplicity.

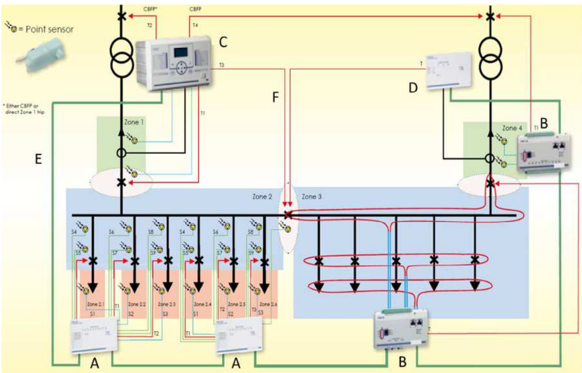


Figure 5. An example of dedicated arc-flash protection system of a MV substation

On the left hand side of the Figure 5 the light is detected by point sensors, while on the right hand side the installation has been equipped with fibre optic sensors. I/O units are reading the sensors and sending the sensor information to the common communication pathway. The point sensors are connected to I/O units in the Zone 2 (A) and the fibres are connected to an I/O unit in Zone 3 (B). I/O units can perform a local trip based on the information from the sensors connected to the I/O device itself or based on the signal from any other I/O unit on the same zone. All the light sensors connected to one I/O unit can only belong to one particular zone. A total of five zones are available, one of which is always reserved for transferring over current information.

Current can be measured by current transformers connected either directly to the arc protection central unit (C) or to current I/O unit (D). All units are linked to the central unit by the communication cables (E). Circuit breakers get their trip command from the central unit or from the I/O units via the circuit breaker wiring (F).

The system architecture is centralized and the central unit is always required. The central unit monitors the system (self-supervision) and maintains the communication. It can also perform a trip based on the light sensors connected to the central unit itself or based on the information received from the I/O units. In addition, the central unit is able to communicate with SCADA systems by using various standard protocols.

## ALTERNATIVES SIMULATED

### Arc durations

In addition to the 1s arc duration, a standard requirement in contracts, two shorter durations have been studied :

- 300ms : consistent with a fault clearing time by a standard protection system, including a tripping delay for coordination with a downstream breaker.
- 80ms: consistent with the implementation of dedicated arc detection system as described § IV.

In both cases, the hot gas flow is simulated 200ms further to the arc extinction, in order to check possible pressure peaks occurring later.

### Absorber technology

A new generation of absorber is used instead of the standard one. It is implemented in a different way: several smaller units are distributed along the plenum (figure 6).

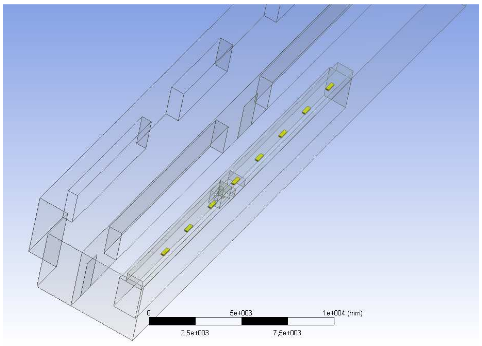

Fig. 6 : implementation of the new absorber on the plenum, CFD model

The new absorber technology is metallic foam. A 3D pattern is reproduced in the 3 directions of space, as a nest of bee (figures 7). A phenomenon of local compression – decompression with turbulences occurs at each step, which fosters heat transfer to the metal, and allows the control of gas speed, as well as of the pressure drop across the absorber.

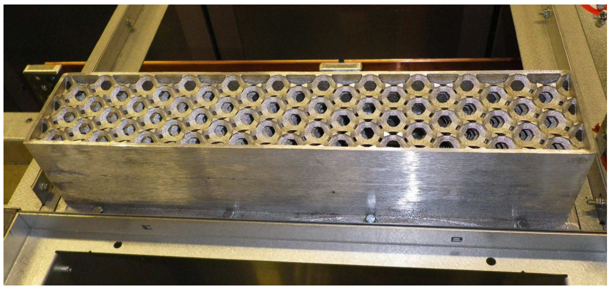

Fig. 7 : metal foam absorber, top side

## RESULTS : PRESSURE ON THE E-HOUSE WALLS - IMPACT ON CONSTRUCTION TECHNOLOGY

### Pressure results : summary

| Pressure (hPa) ($2m^2/16m^2$) | | Ceiling | Side wall | End wall |
|---|---|---|---|---|
| 80ms | existing absorber | 5,3/2,3 | 2,8 | 3,3 |
| | New absorber | 5,3/4 | 3,7/2,7 | 3,5 |
| 300ms | existing absorber | 7 | 7 | 7 |
| | New absorber | 6,5 | 5,5 | 5,5 |
| 1000ms | existing absorber | 19 | 19 | 19 |
| | New absorber | 13 | 13 | 13 |

Peak values are reported. One remark's that as the room is closed, the pressure is rapidly uniform in space within the volume, which is usually not the case when there is an opening through the wall, such as a ventilation grid.

## Qualitative analysis

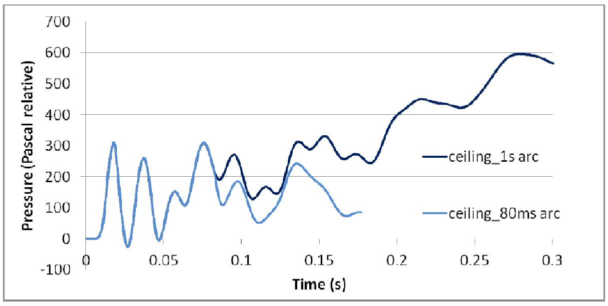


Fig. 8 : pressure rise at ceiling, case with standard absorber, for 1s and 80ms arc durations.

The figure 8 shows the pressure development of the case with the standard absorber, focusing on the 300 first milliseconds. One see's that the first transient peaks occur until 100ms, and that the pressure stays in the same order of magnitude until about 200ms, due to the large room dimensions. Pressure is still not uniform within the room, as shown figure 9. In case the arc is extinguished after 80ms, one see's that the pressure goes down after 150ms.

On the contrary, when the arc last until 300ms, the amount of gas accumulated within the plenum makes the pressure in the room continues to rise slightly after arc extinction.

The absorber technology has few impacts on the first transient peaks, which are of low magnitude. Indeed, at that instant, the pressure is the result of wave propagation, and hot gases have not start to cross the absorbers, so the heat exchange do not actually produce effects. One starts to observe the effect of the heat absorption later, starting at 300ms, and especially if the arc last until 1s.

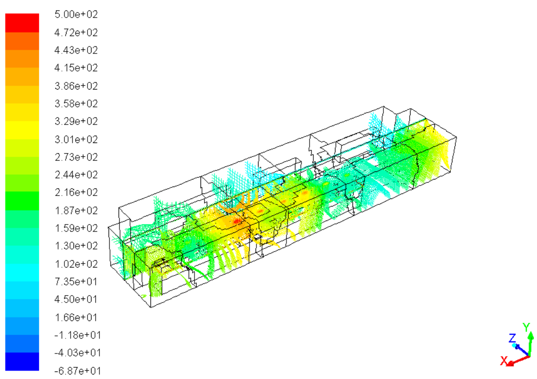


Fig. 9 : Pressure field 80ms after arc ignition, case with new absorber.

## E-House construction techniques pressure withstand

Typical examples of E-House construction techniques are given in this sub-chapter, associated with an indicative level of pressure withstand. This highlights the stakes of arc effect mitigation in the E-House basic engineering choices.

- Sandwich panel: 1000 – 1500 Pa.

Portal frame structure with Sandwich panel directly frame mounted 0.7mm internal and external galvanized sheet with polyurethane core

- Skeletal: 3500 – 4200 Pa.

stud wall at 400mm centers and bracing to all faces.
Portal frame with light gauge internal and external cladding.

- Interlock: 3000 – 3500 Pa.

Interlocking wall and roof panel

- Fully welded: 18000 – 22000 Pa.

Heavy duty portal frame structure
crimped mild steel plate fully welded
Flat plate roof welded to structural secondary steel
Internal lining mild steel sheet

## TEST MEASUREMENTS COMPARED TO SIMULATION RESULTS

Real internal arc tests have been carried out on a primary medium voltage Air Insulated Switchgear, so to characterize the absorbers. It is rated : trip-phase 12,5kA – 0,5s The testing configuration is shown in [6]. Pressure sensors have been installed both sides of the compartments (figure 10).

Figure 10 : pressure sensor locations

The figure 11 illustrates the impact of the standard absorber technology on the pressure inside the switchgear, by comparison with the same shot without absorber.

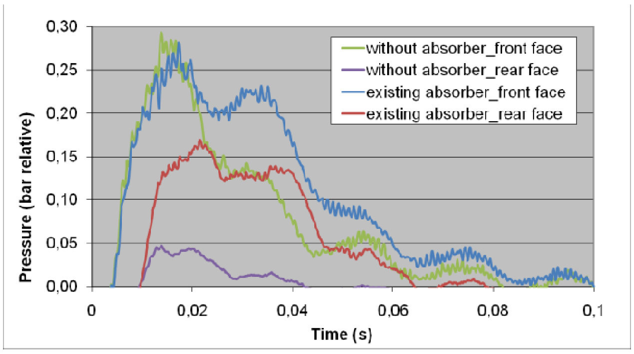


Fig. 11 : pressure measurements, shot without absorber, and shot with standard absorber technology.

Front face, near the arc, the pressure reach almost 0.3bar relative in 10ms. Near the exhaust rear side, pressure rise is delayed, and is limited to 0.05bar. Pressure distribution is then non-uniform within the compartment. After 70ms, pressure is back to zero everywhere.

Figure 12 shows the calculated pressure in comparison with the measured one, for the standard absorber test. The curves match is correct.

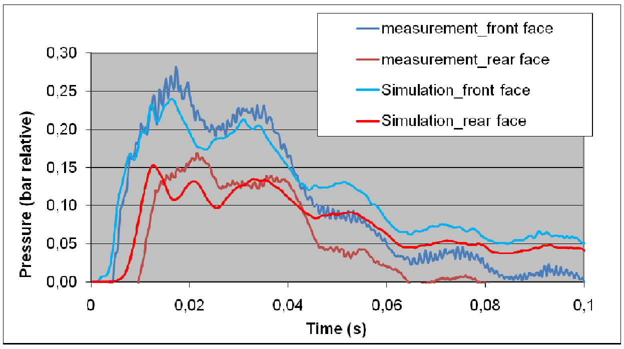


Fig. 12 : Comparison between measurements and simulation results, shot with standard absorber technology

## I. CONCLUSION

The importance of the pressure question within the E-House is related to the size of the E-house on one hand, and to the short-circuit level on the other hand. For small and compact E-House associated with a high short-circuit level, which is often a wish for off-shore applications, the criticality is the highest.

Shorten arc duration provides significant saving in pressure. Still one has to cope with the first transient peaks, that can hardly be avoided, but that should be easily manageable in most of the cases. They are in the range of 5 hPa in our example.

In addition, the improved absorber technology is also an effective passive pressure mitigation system for longer arc durations. It can be combined with fast arc detection systems.

Saving in the E-house construction techniques could be achieved assessing properly the pressure level thanks to the simulation package, however the major benefit is to the end user due to safety in design for fire rated, ATEX/IEC Ex, and blast rated applications.

0,5s could be considered as consistent arc duration for type-tests, for E-House equipped with dedicated arc detection systems, the standard protection system acting then as a back-up.

## II. REFERENCES

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