Environmental installation and operating conditions of medium voltage products: thermal simulation

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ABSTRACT

This article presents: the actions taken for real-time data gathering of the environmental conditions endured by electrical equipment, a design of experiments methodology dealing with the characteristic parameters of ageing and the corrosion phenomenon and finally the possibilities given by thermal simulation tools.

KEYWORDS

Mission profile, Design of Experiments (DOE), simulation, GSM recording device, thermal transfers, relative humidity, condensation, oxidation.

INTRODUCTION

Although the environmental installation and operating conditions are already taken into account in the conception of Medium Voltage products, they must be better understood and perfectly defined, especially for extreme environmental conditions.

This approach permits to ensure a consistent product performance throughout its lifetime and therefore increased reliability. It also gives a better balance between levels of functionality and requirements in order to optimize, for example, energy and exploitation costs, or maintenance campaigns.

The environmental conditions considered are the following:

- ambient temperatures around equipment and their variations (daily, yearly, geographically, …)
- humidity conditions
- solar conditions
- corrosive atmospheres
- altitude

This article is essentially aimed at presenting the actions implemented for real-time gathering of temperature and humidity data and evaluation of the influence of those parameters by using simulation tools and a DOE’s approach.

The equipment primarily concerned is that of the distribution network.

GENERAL IDEAS

The environmental conditions quoted before can be at the origin of a condensation phenomenon and ambient temperature variations (figure 1). Those unfavourable conditions can possibly induce the ageing of the equipment (corrosion of metallic parts, physical/chemical state modification of plastic and thermoset parts) and lead to a decrease of their mechanical and dielectric properties, reducing in the long term the electric and mechanical performances (figure 2).

The following chart (figure 3) relating the behavior of steel shows that corrosion is:

- null for Relative Humidity ≤ 35%
- weak for 35% ≤ RH ≤ 60%
- very important above 60% RH

Figure 1: Condensation phenomenon observed in cell

Figure 2: Mechanical properties variation of a resin according to temperature
Figure 3: Corrosion evolution of steel according to relative humidity

If we want to prevent the steel from corroding, the ideal maximal value would be 35% RH. The corrosion process is highly accelerated above 60% RH.

IN SITU MEASUREMENTS [1]

As stated before, the environmental parameters have been integrated in the technical specifications of our products for a long time. However, this indispensable information, whether it is for the design phase or the equipment exploitation phase, is seen to be insufficient to guarantee the product throughout its lifetime. Indeed, the knowledge of an average value for those parameters, especially the temperature and the relative humidity of the environment, must be completed by a realistic knowledge of the extreme values and their variation amplitude. This leads us to start recording campaigns on representative sites in terms of geographical areas and level of solicitation (figures 4a and 4b).

Examples of installation

Figure 4a: Implementation of a GSM recording device on a site in New Delhi (India)

Figure 4b: Implementation of a GSM recording device on a site in Europe

The recording devices that have been fitted to different equipment installations consist of several sensors and a GSM transmitter. The environmental information is accessible real-time via a website. Figure 5 shows the recording device.

Figure 5: GSM sensor

Examples of recording

Figure 6a: Ambient relative humidity, New Delhi (India), year 2006-2007

We notice high variations and the concrete visualisation of local weather phenomenon (monsoon from June). This is the reason why long term data recording is important (figure 6a).
The common specifications for high-voltage switchgear and controlgear standards IEC 60694 define the normal service conditions for indoor equipment. [2] The measurements carried out reveal that normal service conditions are exceeded on several sites (figure 6b).

DESIGN OF EXPERIMENTS (DOE) [3], [4]
A DOE has been realized in order to quantify the possible interaction between environmental conditions (temperature, humidity) characterized by installation conditions in kiosk and the MV product operating condition, described by physical or functional characteristics of representative components.

In terms of DOE’s methodology the installation conditions correspond to the DOE’s controlled factors and the characteristics of the components to the DOE’s answers which indicate the operating status of MV products. Those components are installed in eight outdoor models. The dimensions and ventilation systems of those models are proportional to real kiosk configurations in order to recreate identical conditions and phenomenon (figure 7). For memory a kiosk is a metallic or concrete cubic integrating all the LV and MV equipment.

Factors affecting the installation conditions in kiosk:
- presence or absence of liquid water
- presence or absence of ventilation
- presence or absence of protection against solar radiation (single or double roof)

The choice of these factors has been influenced by their supposed capacity to accelerate or reduce the ageing process.

The selected components for DOE are representative of industrial components:
- uncovered copper pad
- steel bases with surface treatment (galvanization)
- electrical accessories
- metallic pinions with specific surface treatment
- plastic pinions
- epoxy specimen

Characteristics or responses measured, representative of the operating status or of the product ageing are:
- the function of the electrical accessories
- the corrosion state of the copper and steel components
- the Tg point (thermose’s glass transition point)
- the dimensional measurements of the insulating parts

The tests started in July 2006 and have been realized during one year, around the city of Grenoble (France) under a moderate continental climate.

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Synthesis of the tests’ results and the main conclusions of the experience plan:

- Direct relation underlined and quantified between the qualitative factors (water, ventilation, type of roof) and the degree of relative humidity measured. Thus an equal level of humidity can be obtained for several combinations of those three factors.

- Direct impact between the relative humidity level and the ageing level of the components

<table>
<thead>
<tr>
<th>Ventilation</th>
<th>Water</th>
<th>% RH</th>
<th>Ageing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of roof</td>
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- Notice that in this DOE’s approach we have not taken into account all the factors responsible for the ageing. Some corrosion phenomenon can be generated or activated by pollution. The main pollutants here are the sulfur dioxide SO2 and the hydrogen dioxide H2S.

- This DOE has not shown the influence of temperature linked to the presence of a MV/LV distribution transformer and switchgears, which can increase the ambient temperature inside the kiosk.

THERMAL SIMULATION CONTRIBUTION [5]

In the areas of thermal exchanges and fluid mechanics, numerical simulation has recently become a necessity and must be used on the different steps in development projects, evolution projects (technical managing), implementation and exploitation projects (installation systems), in order to get a product or a system in accordance with the various specifications (marketing, functional, normative, environmental, …) and for which the impact of most of the parameters is or should be understood, estimated and controlled.

This type of simulation allows us a better knowledge of the various input factors impact and their effect on the LV products. This increased understanding allows us to make a quantified choice for products architecture and helps us to lead detailed and exhaustive sensibility studies with several parameters.

See the following examples.

Ventilation control by the optimisation of the openings and their positions:

- Opening characterization in terms of section and resistance to flow.

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![Figure 9: Opening characterization](image9.png)

![Figure 10: Global view of a LV/MV station](image10.png)

![Figure 11: Global view of internal flows and temperature fields](image11.png)

![Figure 12: Detailed temperature fields (external, internal) in a MV equipment](image12.png)
Impact of solar radiation on internal temperatures of exposed equipments.

Figure 13: Global view of a top pylon equipment

Figure 14: Illustration of the solar radiation received on several faces of the product

Anti-condensation resistor efficiency in terms of dimension and position

Figure 15: Anti-condensation resistor efficiency study

Those examples show the areas in which numerical simulation can be used and when, coupled with the different approaches seen in this paper, provide a valuable insight into the operating conditions and requirements of the equipment. A good example is that of knowledge of local temperatures and solar gain.

CONCLUSION

The environmental data gathering, simulation and the experimental approach constitute the fundamental steps of a study design reflecting the real installation and operating conditions of Medium Voltage switchgear systems.

In particular, the in situ measurements allow us to improve the environmental specifications and to better take into account the climatic specificities linked to geographical areas, especially for the emerging countries.

Moreover, the DOE’s approach gives a better understanding of the main parameters and their interactions. Although this experience plan has been realized under a moderate continental climate, with several parameters, we can reach a very high humidity rate, which leads to an accelerated ageing, thus, this process allowed us to identify the factors that accelerate the ageing process. Some specific actions must be distributed to fitters and operators through technical documentation on invitation of tenders or in the instructions attached to the products.

Finally, the thermal simulation tools offer the possibility to evaluate the influence of several environmental parameters on the levels of temperature reached in the switchgear and in its environment. It also allows us to optimize the installation conditions (ventilation, solar radiation control, understanding of the condensation phenomenon, …).

These different elements supply the mission profile which becomes a key entry in the design phase.

REFERENCES