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Thermal behaviour of different fuse enclosure packages in 24kv. SF6 main units

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Abstract

Thermal behaviour of several fuse enclosure packages (F.E.P.) used in SF6 R.M.U. has been studied. For such a study the most common F.E.P. arrangements have been modelled using the Finite Elements Analysis (F.E.A.) technique. Model validations has been carried out by means of laboratory test. Results of this study are shown and analysed.
The obtained calculation model has been successfully applied to the study of several important aspects regarding both design and operation. The most outstanding applications are:

- ❑ Selecting geometry and material for F.E.P.
- ❑ Thermal behaviour analysis of differents F.E.P. designs (three phase enclosures, single phase enclosure, horizontal or vertical arrangement, etc.)
- ❑ Effect over F.E.P. materials of thermal stress increase.
- ❑ Fixing derating of M.V. fuses for proper operation inside a F.E.P.

Background

The IBERDROLA Company is making use of SF6 insulated ring main units (RMU), in its distribution transformer substations, these last few years. The good result obtained during operation predict an optimistics future for this kind of switchgear. The positive influence of SF6 R.M.U. in quality improvement of electric power supply and safety operation in distribution substations has benn noted; especially in those nearby the coast with a high salt pollution level.

Placing of M.V. fuses inside an enclosure, either in a horizontal or vertical position, requires a study in depth of the thermal behaviour of the assembly, aimed to guarantee the proper device operation.

The breakdown of SF6 R.M.U. data, recorded by IBERDROLA up to 1992, were studied. Very significant facts were noted. In a sample of 924 cubicles controlled, selected from among those exposed to the most adverse enviromental conditions. A total amount of five breakdowns took place inside single phase fuse-links enclosures. All of them occurred in cubicles with vertical fuse enclosure arrangement.
(See figure 1). (Accessory Damages showed in the figure mean small defects that did not cause the electrical supply suppression).

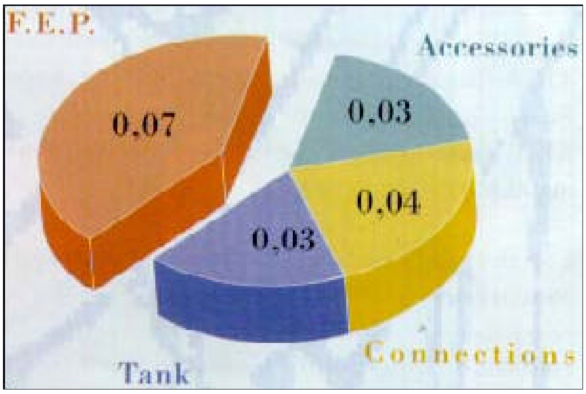


Figure 1: SF6 RMU breakdowns (1984-1992)
Average annual rate in per cent.

When fuse links are used inside an enclosure, it is essential that its rated current be corrected [1], in order to avoid any one of the following problems:

- ❑ Development of too high spot temperatures inside the fuselink that can cause deterioration or change in its operation characteristic [2].
- ❑ Too high temperatures on contacts inside the enclosure, overcoming the limit values specified in relevant standard [3].

Derating of fuse rating current should take into consideration the following effects:

- ❑ Temperature at fuselink surroundings.
- ❑ Fuselink power dissipation.
- ❑ Power disipation of connections within the enclosure.
- ❑ Thermal effect of the enclosure.
- ❑ Fuse enclosure package arrangement in the R. M.U.

Using Finite Elements Method (F.E.M.) it has been possible for IBERICA DE APARELLAJES R&D department to obtain calculation models applicable to fuse enclosure packages which fit properly to the real phenomena.

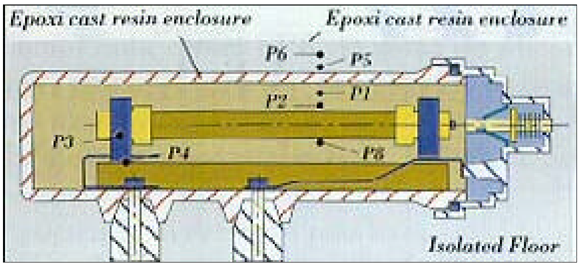
Method Description

For heat transfer phenomena study in a F.E.P. several geometrical models have been used. These models include the following areas: Fuselink, air inside the F.E.P. , air outside the F.E.P. , insulating enclosure (if any) and the outer metal part. (see figure 2).

For the study of temperature distribution the concurrence of three modes of heat transfer are considered: Conduction, convection and radiation. Equation to be solve for a steady-state analysis is that called Fourier Law for heat transfer:

$$-\nabla.(k\nabla.T) = q'''$$

q''' : Heat generation rate.
T: Temperature.
k: Thermal conductivity.



Temperature measurement points
P1 – Epoxi cast resin enclosure inner face
P2 – Air inside resin enclosure
P3,P4 – Contacts
P5 – Epoxi cast resin enclosure outer face
P6 – Air within steel sheet box
P8 – Fuselink barrel outer surface

Figure 2:
Temperature measurement inside a single phase F.E.P.

The calculation was carried out assuming K to be constant with regard to temperature in all materials.
Equation (1) can be easily expanded in the rectangular directions (x,y) (bidimensional case):

$$K_x \frac{\partial^2 T}{\partial x^2} + K_Y \frac{\partial^2 T}{\partial y^2} + q''' = 0$$

The calculation was carried out by mean of a commercial Finite Elements Analysis (F.E.A.) program, running on a 66 Mhz personal computer.
Process consist of the following steps [4,5].

- ❑ Solid modelling of geometry under analysis and meshing for Finite Elements formation.

- ❑ Application of differential equation to an individual finite element.

- ❑ Utilization of standard variational techniques and integration over the volume of element.

- ❑ Obtaining temperatures within each element by means of a nodal approximation using then appropiate shape functions (Ni):

$$T(x,y) = \sum Ni(x,y)Ti$$

Ti: Nodal temperatures
Ni: Shape functions for the elements

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Fuse enclosure packages analyzed

The work focuses on different F.E.P. widely used in SF6 R.M.U. For model validation the following arrangements have been considered.

A) Group of three single enclosures made of insulating material inside a metal compartment in the cubicle. (See figure 3)

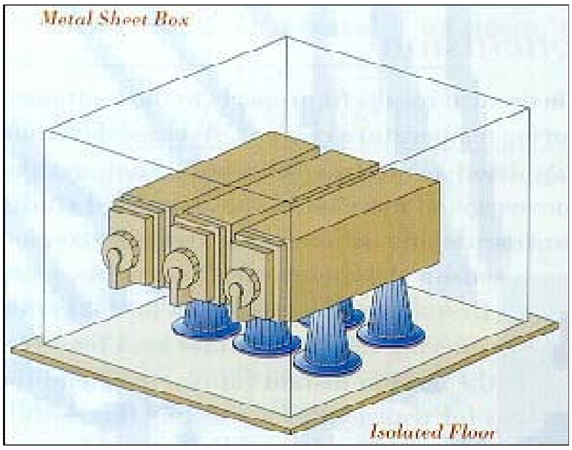
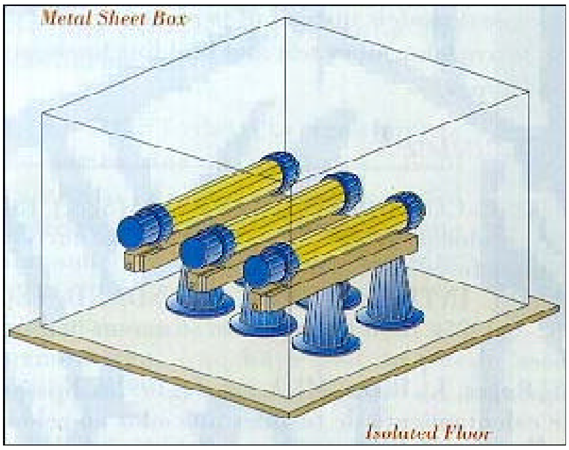


Figure 3:
Fuselinks placed inside single phase enclosures

B) Fuselinks located inside a three phase box type enclosure. (See figure 4)



In the case a), the gap existing between the outer surface of the fuselink and the inner wall of the enclosure ia relatively narrow. In that case, cooling by convection is of little importance. There is an important influence between the fuse and its receptacle that causes the simple calculation procedures for establishing the inservice rating current of the fuse-F.E.P. combination, to be inaccurate. Therefore additional raise temperature tests could be necessary.

In the case b), there is an important amount of heat transfer by convection from the outer surface of the fuse-link to the inner wall of the common enclosure.

Using simple methods (such as annex E of IEC 282-1 [6], can give good results for determining the in-service rated current of the combination. Nevertheless, there is one difficulty: It is important to know the ambient temperature inside the enclosure; but the heat produced by the fuse has a direct effect on the enclosure; but the heat produced by the fuse has a direct effect on the enclosure ambient temperature.

Theoretical Results

For each one of the above mentioned arrangements, a model was developed and it was analyzed applying the Finite Elements Method. Steady-state temperature distribution was obtained.

Power dissipation values, at 50% and 100% of rated current, obtained during power dissipation test [7], adding a term related to power dissipation in fuselink contacts, were used as data entry.

Figure 5:
Isothermal lines. Single phase enclosures

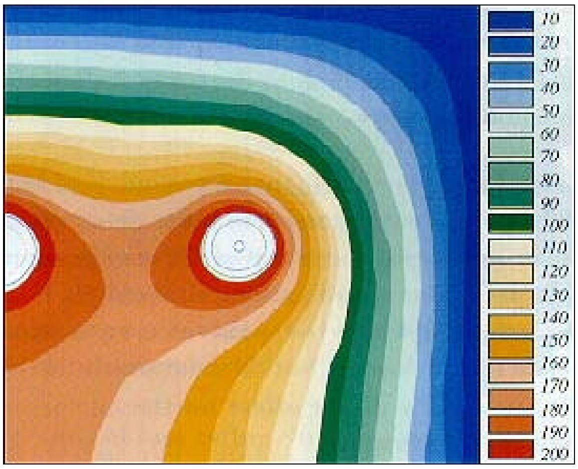


Figure 6:
Isothermal lines. Three phase enclosure

Verification Test

Results obtained of the theoretical model were checked comparing them with values obtained during temperature rise test. A steel sheet box was built with overall dimensions of 840 x 720 x 530 mm. The fllor was thermically isolated to prevent heat transfer from this area towards its surroundings. The two following arrangements were performed:

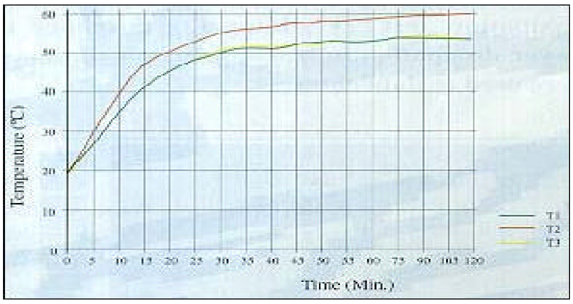


Figure 7:
Temperature inside a three phase enclosure

1) Three fuselinks, without a single phase case, inside a common steel enclosure. Their rated current was applied. Thermocouples were placed for ambient temperature measurement in several points within the enclosure. (See figure 4). Figure 7 shows the results obtained in this test.

2) Three fuselinks, with a single phase insulating case inside a steel box. Inside the box there were mounted three epoxy cast resin enclosures with a fuse inside and hermetically closed. The same case as before, thermocouples were placed for temperature measurement on the following points: Air inside resin enclosure, inner and outer faces of top enclosure wall, air within steel box, and external air. (See figure 2). Figure 8 show the results obtained.

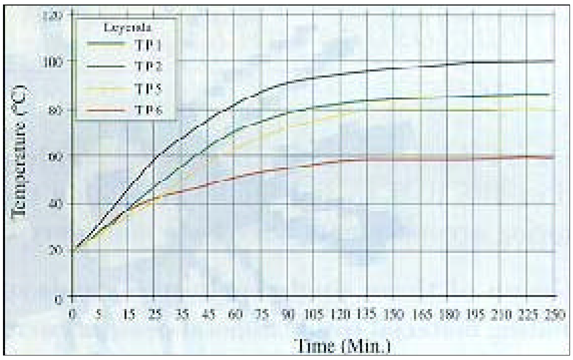


Figure 8:
Temperature inside a single phase enclosure

Conclusion

Theoretical results fit properly to those attained during temperature rise test. Average desviation happened to be less than 5%. Such results encourage an increase in the completed study; contemplating other operating patterns, arrangements, geometry, etc.

In this first stage, the study has been carried out considering the steady-state heat transfer. It is in the not-too-distant future, to extend the analysis for transient processes. By this means, information about fuse-F.E.P. combination behaviour when operating condition changes instantaneously will be able to obtained. Design changes concerning geometry, materials, etc. can be easily studied using the above described models instead of performing a lot of expensive laboratory test and building too many prototypes.

References

[1] IEC COMMITEE DRAFT, 32A (Sec.) 130 “Ammendment to IEC 282-1: High voltage current limiting fuses” (October 1992).

[2] IEC INTERNATIONAL STANDARD, IEC 282-1 (1985) “High voltage fuses. Current-limiting fuses”

[3] Roger J., Riera M., Aspas J., (1991): “ Ensayo de calentamiento de fusibles ubicados en celdas compactas de distribución, para 24 kV, aisladas en SF6”. Portuguese-Spanish Electrical Engineering Meeting. Coimbra (Portugal).

[4] Dhatt G., Touzot G., (1984): “Une presentation de la methode des elements finits”. Maloine, Paris.

[5] Ansys User Guide. “ Heat transfer”. Swason Analysis System, Inc. Houston 1993.

[6] IEC COMMITEE DRAFT, 32A (Sec.) 131, “Ammendment to IEC 282-1: High voltage current limiting fuses. Annex E: Determination o derating of fuses when the ambient temperature exceeds 40ºC.”, (October 1992).

[7] IEC DRAFT INTERNATIONAL STANDARD, 32A(C.O.) 115, “Ammendment to IEC 282-1: High voltage current limiting fuses. Measurement of power dissipation”. (November 1992)