AMORPHOUS MATERIALS AND ENERGY EFFICIENT DISTRIBUTION TRANSFORMERS

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ABSTRACT

This paper deals with EDF Research and Development work for ERDF needs in terms of energy efficiency, focused on Amorphous Metal Distribution Transformers (AMDT). Investigations are carried out on the amorphous material itself including studies of characteristics such as aging, chemical compatibility and properties evaluation. EDF R&D contributes to defining the next amorphous transformers to match the strict ERDF requirements for withstanding short circuit and for noise level limitation. Technical proposals of manufacturers will be analysed next. ERDF plans to make field investigations with the prototypes, involving the main European transformers manufacturers. This will start mid 2010 for a two-year period.

INTRODUCTION

Energy efficiency is a key point in current European policies and an environmental necessity for the future. In accordance with European laws and decrees, utilities involved in the energy sector have to improve equipment, networks or grids and demonstrate efforts made in terms of energy efficiency and energy savings. Previous studies have shown distribution transformers account for the majority of losses in electrical European networks with total losses of about 33 TWh/y [1] in the EU27 and 4 TWh/y in the French distribution grid. For the needs of ERDF, the french DSO, EDF R&D is carrying out studies targeted at efficient distribution transformers. The following chart illustrates the losses in the French distribution grid.

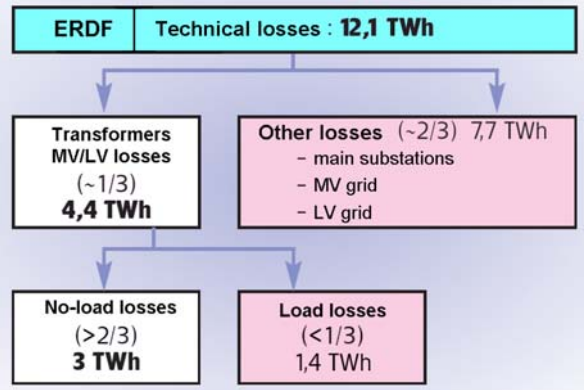

Table 1 : Chart of losses accounting on ERDF grid. [2]

Recent decisions of the European Commission order utilities of the energy sector to reduce losses on their grid and on their equipment. For electrical companies, EDF and its subsidiary ERDF, distribution transformers are pinpointed as equipment to be improved. Where conventional Grain Oriented steel seems to show a limitation in the possibility of no-load losses reduction, amorphous ribbon technology developed by Hitachi Metals/Metglas Inc., allows a significant reduction of these losses of wound core transformers. Compared to conventional Grain Oriented sheets, amorphous wound core based design makes optimum use of the properties of amorphous alloys. A reduction up to 60% is expected on the no-load losses level [3]. Nevertheless, the transformer concept needs to be reviewed to match the amorphous ribbon capabilities and shape. The "5-leg transformer" concept with 4 or 8 wound cores seems to be an optimum design if it complies with electrical behavior requirements notably the short circuit test which induces important mechanical stresses into the active part.

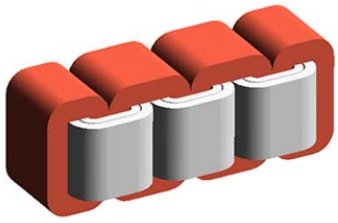

Table 2 : Example of 5-leg type wound core transformer

INVESTIGATION ON THE AMORPHOUS MATERIAL

Before a large scale implementation of AMDT on the French distribution grid, EDF R&D evaluates the material, its magnetic properties, the stability, the chemical compatibility, and the safety aspects in case of transformer failure. For that, a 3-year Ph. D. program has been initiated in 2009, supported by EDF-R&D-LME and titled "Study of application of amorphous ribbons in distribution transformers for ERDF", in partnership with CNRS-ENS Cachan. This first past year was dedicated to the characterisation of amorphous ribbons properties (Metglas 2605 SA1 and HB1) and the study of chemical compatibility with mineral oils and natural ester potentially used in transformers. The aim of these first investigations is to check whether mineral oil and natural

ester have an impact on the amorphous ribbon properties. EDF R&D and ENS Cachan have performed an isothermal aging test to artificially simulate an environment comparable to what the transformer may be exposed to over the 30 years of service conditions. The ribbon samples were submitted to 140°C heating during 580 hours, immersed into the three referenced oils usually used at ERDF. Magnetic properties were periodically recorded and compared to initial values.
At the end of this test, we concluded the properties are stable and no degradations occurred in the samples. This step shows the amorphous soft alloys are of interest and offer many advantages for efficient transformers applications.

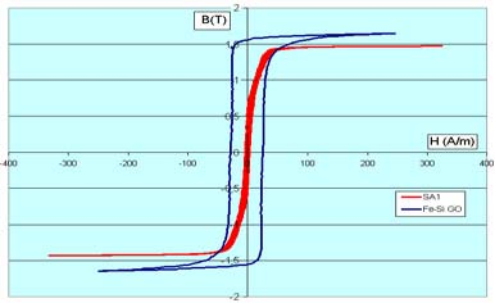

Table 3: Hysteresis cycles measured on G.O steel and amorphous ribbon.

The ability of amorphous ribbons to withstand aging was checked with XRD measurements. A pure halo is the proof of a controlled manufacturing process.

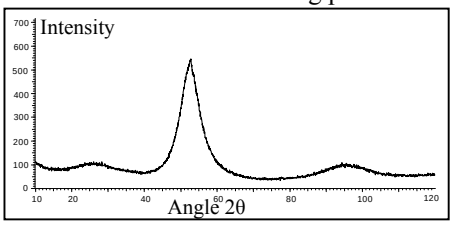

Table 5: XRD pattern of a SA1 amorphous sample.

We also pushed the limits of the investigation, studying a crystallization under high temperature as the manufacturer Hitachi Metals/Metglas describes it at temperature thresholds.

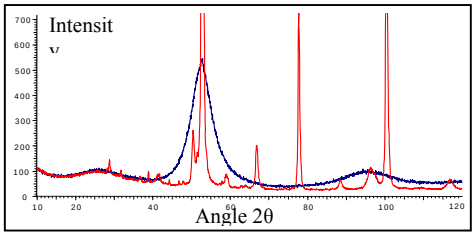

Table 6:XRD patterns of crystallized and amorphous ribbons

Fe-Si and Fe-B compounds are clearly detectable with singular peaks. This situation is out of the normal operating range of the amorphous material.

ERDF REQUIREMENTS

In 2010, ERDF asked transformers manufacturers to develop prototypes complying with the current transformers specification. Dimensions and weight criteria shall be respected and stay similar to those of conventional transformers already approved. As for conventional transformers, ERDF wishes the next AMDT to withstand short-circuit attempts in accordance with IEC 60076-5. The sound power level stays similar to that of the last generation of transformers already approved. The major change is the no-load losses level which will be based on EN 50464-1 and will not exceed $A_0/2$. If better performance can be reached, it is welcome.

Short circuit withstand	Max deviation 4% (ΔL/L)
No-load losses level	A_0 / 2

ERDF will evaluate the devices having various characteristics such as the noise level. The purpose is to know the feasibility and the impact of various criteria on the final cost of the transformers.

FIELD TEST EXPERIMENT

For the next couple of years, ERDF plans a trial test with some amorphous-core 3-phase transformer prototypes, 250 and 400 kVA, built early in 2010 by manufacturers who invested in this technology. The purpose of the campaign is to build and to install amorphous transformers in pad mounted type substations of the ERDF distribution grid. They will operate in usual conditions including thermal cycles and load cycling. At the end of this 2-year period, a sampling of these units will be re-evaluated in the laboratory in order to compare their performance with their initial data. The noise criteria, the aging, the general behaviour, the field team's opinion will be monitored in particular.

CONCLUSIONS

During the first stage of these investigations, the compatibility of amorphous ribbon with mineral oil and natural ester was demonstrated. The characterisation step brought us a better understanding of the material limits and what we can expect from it. Dedicated specification for AMDT will be produced soon in 2011, before launching an AMDT supply contract in the French territory. These long terms investments match the commitments of EDF Group in grid losses reduction, according to the European requirements on energy efficiency and energy savings.

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