AMORPHOUS DISTRIBUTION TRANSFORMERS TRIAL TEST CAMPAIGN

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ABSTRACT

Amorphous Metal Distribution Transformers (AMDT) are well-known for its very low no-load losses level. Before the ERDF, the French DSO, takes the decision of a possible larger implementation of amorphous transformers on its grid, a field test campaign is launched to evaluate amorphous transformers prototypes. ERDF intends to investigate 20 prototypes from 5 or 6 international manufacturers. These experiments are been carried out in partnership with ERDF and EnBW. The purpose of the campaign is to evaluate the next generation efficient transformers under site conditions for prototypes developed according to ERDF specifications notably with respect to short circuit withstand. In summer 2010, EDF R&D started the test sequence in order to deliver prototypes on trial, for the earliest, to operating teams by this autumn 2010. Other prototypes will be installed along the coming year. This field trial is a major step before a possible implementation of amorphous transformers in France and an opportunity given to manufacturers to promote their development. By the end of 2010, 5 prototypes are operated on various sites of the ERDF and EnBW grids randomly selected, with no more or less severity in the load profile. According to these experiment results, ERDF will evaluate the real impact and capital gain of the amorphous technology before launching a bid for tender for marketing in 2012.

INTRODUCTION

Since 2006, European Union invites DSO to invest in high performance equipment for environmental and economical reasons. This incentive does not assign a particular technology but gives manufacturers the possibility to use G.O steels or amorphous materials to build the transformers core. Losses reduction is an important economic issue for ERDF, subsidiary of EDF. This article describes the investigations carried out by ERDF on AMDT to which EDF R&D contributes, leading to a trial test campaign. Iron based amorphous ribbons are one of promising possibilities for improving efficiency of transformer cores and enlarging the panel of raw materials suppliers. Amorphous technology seems to have proved its efficiency in numerous countries but the 5-leg core concept needs to be tested according to French requirements notably with the short circuit withstand test. Economic model of AMDT, applied to the west European market conditions, needs to be confirmed as well. A trial test campaign is launched in 2010 to evaluate the prototypes feasibility. This evaluation is an opportunity for manufacturers to design an AMDT which complies with ERDF and EnBW requirements and satisfies operating conditions.

REQUIREMENTS AND TESTS RESULTS

For the trial test campaign, ERDF and EnBW need 5 AMDT from each manufacturer volunteer and available to participate in the experiment. The expected prototypes are 2 units rated 250 kVA and 3 units rated 400 kVA available in 2010 and 2011. The ERDF requirements are those used for conventional transformers based on the specification HN52-S27 except for the no-load losses and the acoustic power levels, both inspired from the EN 50464-1.

Rated power	**250 kVA**	**400 kVA**
Noise level	Co (55 dBA)	Co (58 dBA)
Po (W)	Ao/2 (150 W)	Ao/2 (210 W)
Pk (W)	Ck (3250 W)	Ck (4600 W)
Weight	1500 kg	2500 kg

For its part, EnBW intends to test four rated power prototypes. The requirements are not the same as ERDF and summarized in the following table.

Rated power	No load losses level	Load losses level	Acoustic level
160 kVA	Ao/2 (100W)	Bk (2000 W)	Co – 52 dBA
250 kVA	Ao/2 (150W)	Bk (2750 W)	Co – 55 dBA
400 kVA	Ao/2 (210W)	Bk (3850W)	Co - 58 dBA
630 kVA	Ao/2 (300W)	Bk (5400W)	Do – 65 dBA

About the load losses level, the German distribution grid is designed to supply a higher population density in the cities where the feature "Bk" is often the most relevant.

Short Circuit tests withstand results

The short circuit withstand tests are performed according to the specification HN52-S-27 referring to IEC 60076-5 with a maximal deviation of ΔL/L restricted to 4%. The reason is the distribution grids may be subjected to third parties damages due to hits on underground cables or bad weather conditions, tree falls on overhead lines or else. This also illustrates cares and quality brought along the manufacturing process. The following table summarizes the results obtained after the tests carried out in the EDF R&D laboratories.

Manufacturer	Year	Rated Power	Max Deviation over 3 ph.	Results after SC test	Acoustic level (dBA)
M1 - Tr1	1997	400	6,0 %	NS	65
M2 - Tr1	2008	400	0,5 %	S	65
M3 - Tr1	2009	400	1,4 %	S	61
M3 - Tr2	2009	630	3,0 %	S	55
M4 - Tr1	2010	250	1,6 %	S	48
M4 - Tr2	2010	400	6,5 %	NS	49
M5 - Tr1	2009	400	5,0%	NS	63
M5 - Tr2	2010	400	5,9 %	NS	63

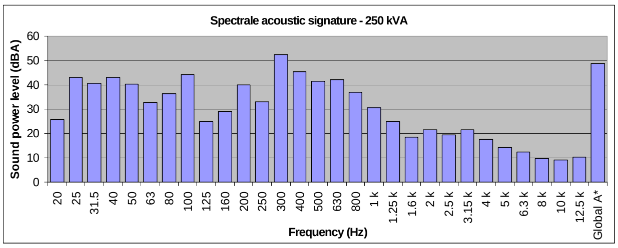
S : Satisfying NS : Not satisfying

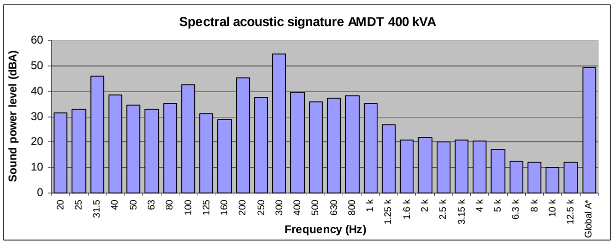
Prototypes failing the short circuit withstand test are refurbished by the manufacturer. The solution is sometimes a question of active part mechanical adjustments or a question of core packaging in order to avoid flakes or metallic particles synonym of partial discharges activity.. We are concerned about flakes scattered into the active. This could affect the dielectric behaviour later on, prejudicial to reliability and safe operation. For the moment, we estimate the risk is getting higher for AMDT if the deviation due to the short circuit reaches 7,5% of ΔL/L as mentioned and allowed in the IEC 60076-5 as it is for conventional transformers. Some units comply with the requirements with respect to the SC test but do not satisfy ERDF expectations in term of sound power level.

AMDT 250 & 400 kVA acoustic and spectral signature

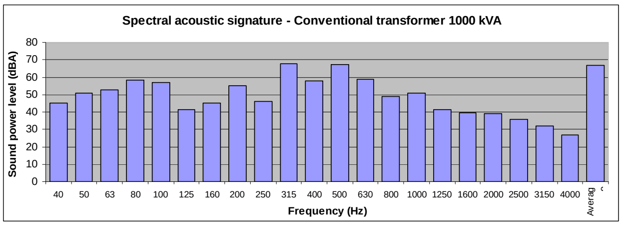
For two representative amorphous transformers, EDF R&D carried out an acoustic spectrum measurement. The goal was to plot a noise profile in order to identify if these units could be generator of a singular noise pollution. A lightly higher emission can be noticed around the 300 Hz band, comparable to the 5th harmonic. The active part and its windings generate these sound waves. The phenomenon is met on both technologies. These prototypes installed into a substation fulfil the French regulation.

Example of spectral signature for AMDT 3 Ph 20kV/410V





Spectral acoustic signature for a conventional transformer rated 1000 kVA



With the criteria chosen by ERDF and EnBW, AMDT are complying with for an implementation in substations.

Investigation during R&D PhD program

A PhD thesis was initiated by EDF R&D in 2009. The working program consists in various investigations on the material itself. At first, physical properties of the material were studied and in a second stage the material into the equipment and its impact on the grid. The PhD student works in partnership with ENS Cachan. Among the topics studied, investigation results demonstrated the full compatibility of the ribbon with transformer oils. In order to insure ERDF the amorphous ribbon performances are steady in the time, accelerated aging tests have also been performed. The tests conditions were 150°C during 600 hours. It was shown the ribbons keep their structural state with the following results, according to Arrhenius law.

	Metglas®2605SA1	Metglas®2605HB1
Lifetime	> 5000 years	600 years

In 2011, studies will target the transformer behaviour under harmonic conditions. Special measurements are being carried out on miniature cores made of Metglas®2605SA1 and Metglas®2605HB1 materials.

All along our investigations on the materials Metglas®2605SA1 and Metglas®2605HB1, Metglas - Hitachi Metals Europe answered our questions and brought us the support for performing all the tests we intended to do.

LIFE CYCLE COST

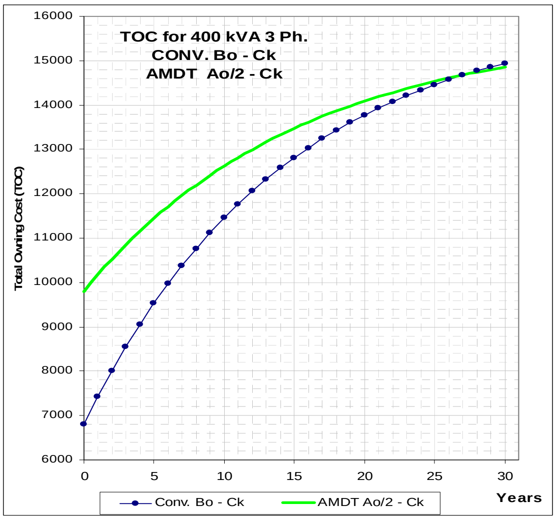
Distribution transformers have a expected life cycle of 30 years and work in a continous operation mode. Consequently, even a small improvements on the efficiency can add up to significant energy savings over the lifetime of the transformer particularly for the no-load losses. ERDF and EnBW purchasing policies apply the principle of the Total Owning Cost (TOC) taking into account the losses cost

$$TOC = C_{purchage} + \sum_{0}^{n} (A \times P_o + B \times P_k) \times \frac{1}{(1+i)^n}$$

added to the purchase price. This TOC value is evaluated to select transformer suppliers.

Parameters A and B represent the no-load and load losses purchasing costs (€/W) of each DSO.

For example, the charts below illustrate the losses cost capitalisation along the transformer life time taking into account the purchasing cost. The TOC is calculated for 2 transformers, the first one is conventional, the second one is amorphous type, both are 400 kVA – 3 ph. 20 kV/410V. Dedicated economic parameters will be provided by each DSO before a bit for tender program.



This illustrates the effects of the initial purchase cost and the losses capitalisation, as comparison Conventional/AMDT. The amorphous technology transformers must become economically relevant to be recognised and adopted by European DSO.

ON SITE EXPERIMENT – EXAMPLE

The aim of this trial test campaign is to test prototypes under real service conditions. It is also an opportunity given to manufacturer to develop prototypes complying with the French requirements. For the French an d German DSO, this first experiment gives an overview of what will be the organisation of AMDT manufacturers in a near future and their capability to manage the next ERDF needs in terms of high efficient transformers.

By the end of 2010, two prototypes are already in service. ERDF and EnBW expect eleven additional prototypes for 2011. It is reasonable to think other manufacturers will join this trial test campaign. The following picture is an implementation example of 20kV/410V – 400 kVA - 3 Ph. amorphous transformer installed in a Parisian suburb.

AMDT 400 kVA at ERDF Tisans Substation, near Paris.

CONCLUSIONS

Before a possible larger implementation of AMDT in France and Germany, ERDF wishes French and European manufacturers get involved in the production of high efficiency transformers. According to these trial test campaign results, ERDF and EnBW encourage manufacturers to develop affordable transformers taking into account the TOC (Total owning Cost) over 30 years. Thanks to these investigations ERDF is been evaluating the real impact and capital gain of the amorphous technology before launching a bid for tender for marketing in 2012.

No-load losses reduction in Distribution transformers is at present a technical issue and part of EDF Group commitments in terms of eco-efficiency and an eco-friendly use of raw materials and primary energies.

REFERENCES

VITO working Group & BIO–IS : Report 2010

R. Targosz, F. Topalis and W. Irrek, "Selecting energy-efficient distribution transformers: A guide for achieving least-cost solutions," SEEDT Project (2008).

ERDF : Vouloir Savoir n°178, p.1, décembre 2008.

H.W. Ng, R. Hasegawa, A.C. Lee and L.A. Lowdermilk, "Amorphous alloy core distribution transformers," *Proceedings of the IEEE*, (1991), p. 1608-1623.

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