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Innovation in Transformer Manufacturing
Amorphous Metal Cores for Environmental-Green Transformers
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International Association «TRAVEK»

INNOVATION IN TRANSFORMER MANUFACTURING

AMORPHOUS METAL (Fe-based) CORES for ENVIRONMENTAL-GREEN TRANSFORMERS

Selim Yürekten, ENPAY Transformer Components

Abstract

Distribution transformers with amorphous metal cores (AMDT) have been started to produce in the years of eighties. They have been used for more than 25 years. Initial interest in their use in electrical power distribution systems stemmed from the first oil shock in the mid-1970ies as improved energy-efficiency in power distribution was increasingly needed. The type of the core is that (wound core) cold distributed gap core. Also stacked core design is on development. Amorphous core loss is approximately 25-30 % from (conventional type CRGO) cores. It shows the magnetic performance curves in next pages. In recent years global trend is that to use this type of cores in a tremendously increasing amount. Worldwide market share of AMDT is quite significant with about 3 million single phase units and a few hundred thousand three phase units. It represents about 5 % market share worldwide. The technical specification of the amorphous metal ribbons and core technologies are given in the next pages.

Keywords

Amorphous metal, CO2 emission, energy saving, magnetic performance, distribution transformers (AMDT), transformer cores

Introduction

ENVIRONMENT AND TRANSFORMER LOSSES – GOALS [1], [5], [7]

It is generally well known that significant studies are being carried out for the reduction of CO2 emissions that causes global warming. In this sense, to reduce losses in transformers means to contribute to decrease greenhouse gas emissions, by reducing the production of loss energy.

The Global Carbon Disclosure Project –CDP which is parallel to both Kyoto Protocol and also the adjustment of EU; by turning hand to Turkey also ; causes the big investments projects if they have no plan for energy and environment to be deprived of credit of international banks. India levied the carbon tax; it is also likely soon for

Turkey. Germany planned to produce the 80 % of its electric energy needs until 2050 from renewable energy sources. (3,360 TWh). Today this figure is only 305 TWh.

It is reported in 3rd International Energy Innovation Conference (SEEDT) [1] that the total losses of 27 EU' electrical grid are given as 8 %, and 30 % of this figure is occurred in distribution transformers and 70 % of this arised from core losses. Transformer losses on load consists 30 %of total losses (33.4 Terawatt hours / year) (Approximately 5 million distribution transformers operate in EU grids). The losses occurred in transmission lines are 34 %, and in the distribution lines 36%.

The EU set the following targets for its 2020 energy policy with 20-20-20 formula.

Accordingly, by 2020:

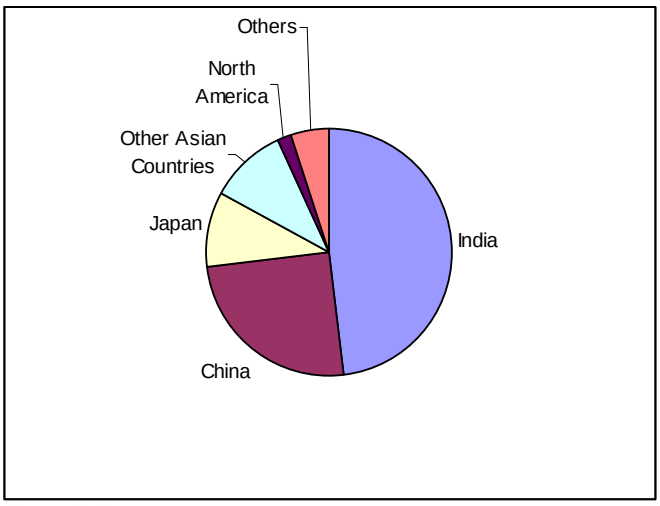
Losses will be reduced by 20 % - CO2 emissions will be reduced by 20 % - the use of renewable energy sources will be increased by 20 %.

EU (European research: Initiatives from SEEDT Project / Intelligent Energy Europe), has started a study since 2008 with relevant partners in France, Germany, Italy, Spain, Poland, Greece regarding this issue since 2008 and set the following targets:

- Determination of allowed maximum losses as European Standards
- Determination of incentives and rules for High Efficiency Distribution Transformers
- Setting the principles of energy efficiency in the classification of Distribution Transformers
- The calculation of potential savings in EU-27 (TWh, of CO2, equivalent to…)

GLOBAL TREND

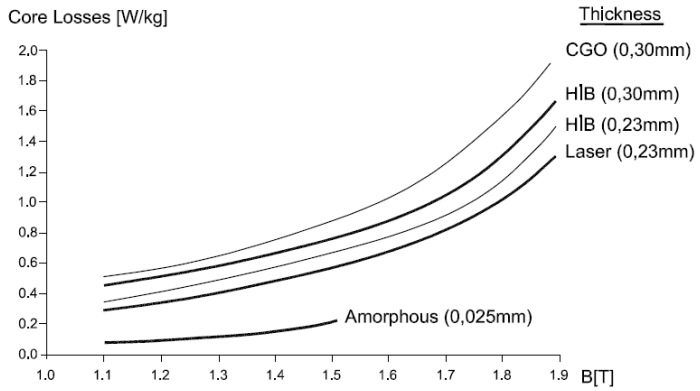
As of 2006, the worldwide use of distribution transformers with amorphous metal core



Asian and Pacific countries such as India, China, Japan, Korea, Taiwan, Philippines, Vietnam, Nepal and Bangladesh, are giving priority to the use of high-efficiency distribution transformers of this type.

USA have new standard for AMDT as ''Distribution Transformers Energy Conservation Standards Final Rule'' since October 2007. Currently India has the largest installed base, surpassing the US. The increase of power production in India is nearly 78 600 MW according to the 11. plan which was valid in these years. The power of distribution transformers that will go into the grid is 54 000 MVA annually. (Approximately 850 000 units, the average unit power 63 kVA). In case, all of these transformers are amorphous metal cored, the production power to be saved corresponds to a power plant with 175 MW. India that has scarce sources has been using high quantities of amorphous metal cored distribution transformers for many years.

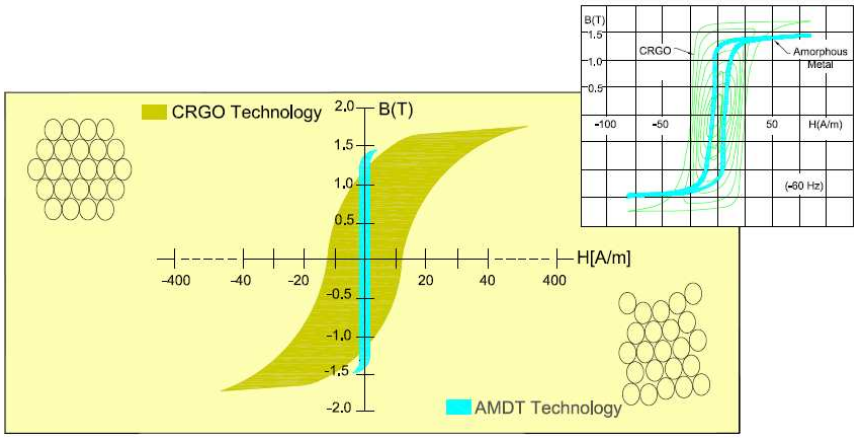
MAGNETIC PERFORMANCE



The losses due to induction in the cores produced with various transformers sheet.

Hysteresis curves of amorphous metals are seen below. Superior skills are as follows;

- Easy magnetization (low coercive, high permeability)
- Low magnetic losses (low coercive, high permeability, high resistivity)
- Fast flux reversal (as a result of low magnetic loss)



Comparison chart of amorphous metal material and CRGO [2], [3], [4], [6]

Unit		Amorphous Metal Material	CRGO Material
Specific Gravity	gr/cm^3	7, 15	7, 65
Resistivity		130	45, 00
Saturation Induction	Tesla	1, 59 – 1, 64	2, 03
Typical Core Loss (50Hz, 1,4T)	watt/kg	0, 20- 0,3	0, 90
Thickness	mm	0,022–0,030	0, 27
Filling Factor		0,86	0,97
Supply type		band/roll	Roll
Annealing Heat	ºC	360	810
Annealing Atmosphere		inert gas	inert gas
Annealing Property		magnetic field	-

Several properties of amorphous metal presented a challenge to the designer of AMDT unfamiliar with this material. It is very thin, very hard, very stresses sensitive and requires annealing under a magnetic field to achieve optimum performance. Core losses have two components, one is eddy current losses, and the other is hysteresis losses. You see this ratio below in amorphous sheet and CRGO steel.

A-Core losses under linear loads

1-Losses in amorphous cores; 33 % eddy current losses, 67 % hysteresis losses.

2-Losses in CRGO cores; 67 % eddy current losses, 33 % hysteresis losses.

B-Core losses under non linear loads

1-Losses in amorphous cores =1, 3 x linear loads amorphous cores

2-Losses in CRGO cores =1, 8 x linear loads CRGO cores

Result is that amorphous cores have under harmonics (non linear loads) big advantages.

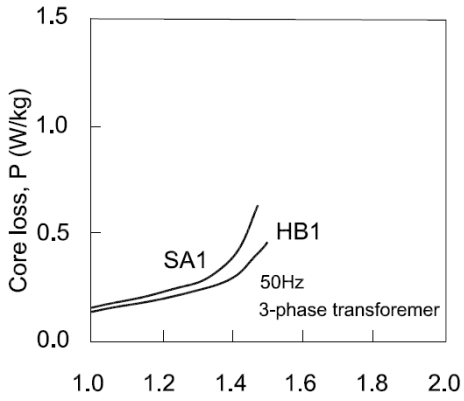
The measurement values in one 400 kVA transformer are given below as compared;
On linear loaded transformer (7):
Total core losses: In AMDT 198 Watt and CRGO transformers 608 Watt.

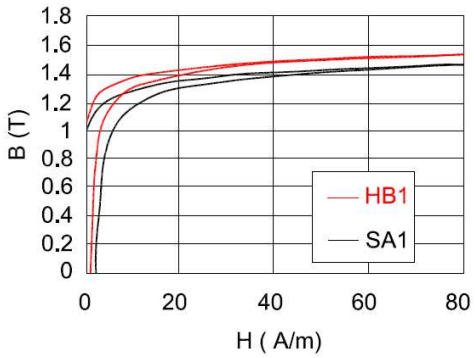
If the same transformer is loaded as non linear, the current and voltage harmonics will cause this loss to increase. However, the loss that increases to 260 W in transformer with amorphous metal; rises to 1113 W in CRGO cored transformer. On the other hand, no load losses in the type of jointless core used in HEXATRANSFORMERS decrease to this record minimum values:
100 KVA / 15 kV. 50 Hz. no-load loss in oil-type is only 34W. 1000kVA / 15 kV.50 Hz. no-load loss in dry-type is 318 W. (However, no load loss of this transformer core in M4 silicon steel is 2334 W)

The saturation induction of amorphous metal ribbons that have been produced up to present is approximately 1.58 Tesla, but recently with the technical improvements in production this value has increased to 1.64. The saturation in CRGO steels is 2 Tesla. For this reason, winding copper is a little bit more in transformers with amorphous metal core and transformer dimensions are larger. Magnetic noise (magnetostriction) is about 53 dB at 1.4 T. at amorphous metal cores. In recent years, Electricity administrations have marked down transformer induction values in the technical specifications fairly. Regarding to this, the differences of the transformer dimensions are getting smaller. Generally speaking, noise is about 6%higher than CRGO steel transformers.

To sum up the main target is that the noise will be reduced even more, dimensions will become smaller (core filling factor will be grown > 84-86%), saturation induction Bs will be raised, the costs will be reduced as an economic result; the competition between amorphous metal and CRGO will increase.

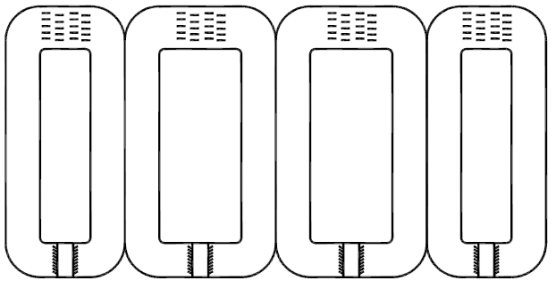
In the world market two kinds of qualities Fe based amorphous ribbon SA1 and HB1 are available. The core loss and induction values is shown on the graphic left and in the right graphic B (T) and H (A/m) values is shown. [1], [8], [9]



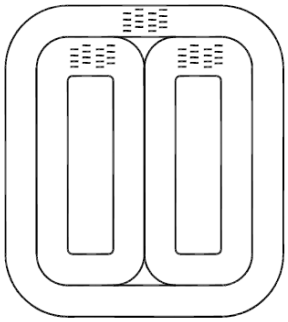


CORE PRODUCTION

Wound core (distributed gap core) technology uses one with/core. This results in a rectangular cross section of the core. The pictures below are showing different design of cores. Single phase and 3 phase cores.



3 phase 5 limbed transformer core group



3 phase 3 limbs transformer core group

Some samples of the single phase transformer cores (ENPAY)

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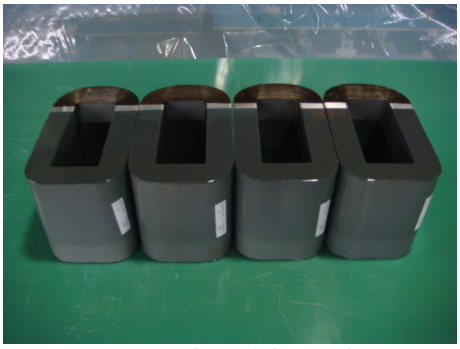
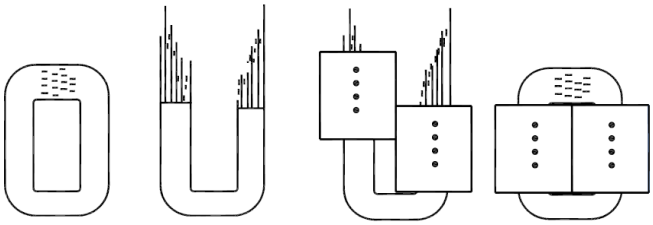


Some samples of the 3 phase, 3 and 5 limbs transformer cores (ENPAY)

Production line of the AMDT cores (ENPAY)

COILS and ASSEMBLE

In order to assemble the active part, rectangular shaped coils have to be used. LW side is preferred to use foil winding, HW side wire winding. Rectangular wires and foils have the best ‘’filling’’ factor per unit area in the core window, particularly when compared to round wire. However some manufacturers have used ‘’flattened’’ wire.



The picture above shows opening the upper yoke of the core, settling the winding bobbins and closing the upper yoke of the core.

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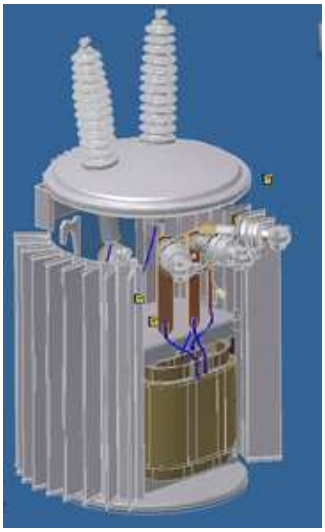
As example of AMDT technical specs in different powers.

Voltage 15 / 0, 4 kV. 50 Hz. 3 phase, oil immersed

Power kVA	No load loss,W	Power kVA	No load loss, W
50	43	630	320
100	75	800	380
160	100	1000	450
200	120	1250	530
250	140	1600	630
315	170	2000	750
400	200	2500	900
500	240		

The biggest power that has been produced all over the world till today is 12 MVA.

3 phase oil immersed AMDT



Single phase oil immersed AMDT

3 phase cast resin type AMDT

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CONCLUSION

European transformer producer can be able to provide NEAR 3 TIMES the 20 % of LOSSES REDUCTION GOAL that could be applied with Distribution Transformers in EU-27. Particularly, this service will be commonly used in wind and solar energy systems. This is a great development on a global scale and in the same time it is transition to a new transformer technology.

Technical challenges are for AMDT;

- Noise reduction
- Size reduction
- Higher Bs
- Cost reduction
- Competition of both technologies: CRGO vs. AMDT

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