

## Contact us

For more information please contact:

**ABB Ltd.**  
Affolternstrasse 44  
P.O. Box 8131  
CH-8050 Zurich, Switzerland

500 West Highway 94  
Jefferson City, MO 65101  
USA  
Phone: +1 573 634 2111  
Fax: +1 573 635 6275

[www.abb.com/transformers](http://www.abb.com/transformers)

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Transformers

ABB green distribution transformer program  
Partnership in a sustainable environment

Power and productivity  
for a better world™ **ABB**

Power and productivity  
for a better world™ **ABB**

# ABB – your sustainability partner

## Introduction

Did you know ABB's line of distribution transformers can reduce operating costs, energy bills and overall environmental impact?

Our low-loss transformers can decrease electrical losses significantly. In fact, if all transformers were replaced by amorphous metal core transformers, our newest technology, distribution network losses could be reduced up to 70 Percent. These energy savings would ultimately mean lower operating costs and reduced environmental impact.

As an added performance and environmental enhancement, our low-loss transformers can be specified with our proprietary high temperature and biodegradable insulation fluid, BIOTEMP®. ABB transformers with BIOTEMP® fluid offer the optimum combination of performance and safety.

Let ABB be your partner in developing all of your future distribution transformer requirements. Simply put, ABB's transformers are the ultimate solution in addressing total cost of ownership (TOC), environmental and safety issues, and energy efficiency.

**Welcome to ABB's world of modern technologies.**

## Sustainability

There are myriad definitions for sustainability but most acknowledge the responsibility that we all have in balancing the economic needs of society with social and environmental impact. As the world population will most likely reach between six and nine billion by 2050, we need to find ways to consume the Earth's resources at a rate by which they can be replenished.

Energy conservation and CO<sub>2</sub> emission reduction need to be a focus for environmental sustainability. Globally, CO<sub>2</sub> emissions into the atmosphere are reaching 30 billion tons a year with concentrations having increased 140 Percent since the pre-industrial revolution.

As our demand and cost for electrical energy grows with the world population, CO<sub>2</sub> emission will also be on the increase. So, finding ways to increase the efficiency of our electrical infrastructure is an important factor towards reducing emissions and costs. Higher efficiency in the form of reduced losses can lead to avoided cost of generating additional electricity while lowering total ownership cost of the electrical infrastructure.

**ABB is the leading, global transformer manufacturer.**

ABB offers a complete portfolio of single phase and three phase pole and pad mount liquid filled distribution transformers, ranging from 15 kVA to 10 MVA, up to 36 kV. All products in our portfolio are in full compliance with IEC and ANSI/IEEE standards. Our transformers are produced in a virtually connected global network of 18 factories. A common technology platform comprising the best practices and systems is deployed within this network to ensure a replicable, reliable product in terms of quality and performance.

Concurrent with its leadership position, ABB is committed to develop all its products to meet ever increasing environmental and higher efficiency requirements. As such, ABB takes into account the entire life cycle (cradle to grave), resulting in the most environmentally friendly products, systems and solutions possible.

**In line with this business philosophy, ABB has introduced a green transformer portfolio for distribution transformers.**

In addition to ABB's existing low loss, high efficiency transformers, we have introduced new technology products which offer even more energy savings, including liquid-filled amorphous metal (AM) transformers and our proprietary biodegradable, high fire point BIOTEMP® fluid.

## The ABB green distribution transformer program

The ABB green transformer program offers a modularized approach for product selection. The design features and options available are:

- Copper or aluminum windings, with paper or enamel insulation
- Step-lap stacked cores or wound cores
- Grain oriented core steel, ranging from M5 to domain refined, and amorphous metal for the ultimate in low losses
- A variety of insulating liquids including mineral oil, silicone oil, synthetic ester based fluids, and ABB superior dielectric insulating fluid, BIOTEMP®, which is a natural ester-based fluid with improved temperature performance and oxidation stability
- Hermetically sealed or conservator type tanks, with corrugated fin walls or radiators
- Surface treatments, with water based or powder painting in different RAL colors, or hot dip galvanization for aggressive environmental conditions

Supported by ABB's leading and extensive global transformer R&D base plus highly flexible design tools, this approach will facilitate a high speed customization to meet desired customer criteria and requirements. Ultimately, products selected from the above modules will provide ABB customers with high efficiency and environmentally friendly solutions.

## Increased transformer efficiency

A testament to the importance of energy saving programs and energy efficiency requirements is present in several widespread global and local initiatives.

Examples of mandates or standards requiring high efficiencies in distribution transformers are: US Department of Energy's mandated National Efficiency Standard, Australia's Hi efficiency 2010, India's 4 and 5 Star programs, China's SH15 standard, and the AKA0 standard in Europe.

Efficiency (Percent) is a measure of how well a device converts input energy into useful output - be it electrical power, mechanical work, or heat. Distribution class transformers have efficiencies well above 90 Percent.

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The efficiency of a distribution transformer increases with a reduction in its load and losses. The transformer load losses decrease with the load, while no-load losses are a constant, independent of the load. Since most transformers are rated to handle peak loads which only happen at certain intervals during the day, distribution transformers can remain lightly loaded for a significant portion of the day. So, specifying the lowest no-load loss possible reduces energy consumption, goes hand-in-hand with increased efficiency, and can increase revenue for a power producer.

## Lowering Total Ownership Cost

In light of global climate concerns, many users agree that low loss transformers should be chosen on criteria other than pure short term profitability aspects. When purchasing transformers, ABB recommends the use of total ownership cost (TOC) which considers the future operating costs of a unit over its lifetime, brought back into present day cost and then added to its total purchase price.

In calculating TOC, the losses are evaluated by their financial impact, capitalized for an expected payback period for the transformer.

$$TOC = C_t + (A \times P_o) + (B \times P_k)$$

$C_t$  = Transformer purchase price

$A$  = Assessed financial value (e.g., USD/W), or capitalization factor, for no-load loss

$B$  = Assessed financial value (e.g., USD/W), or capitalization factor, for load-loss

$P_o$  = No load Loss

$P_k$  = Load Loss

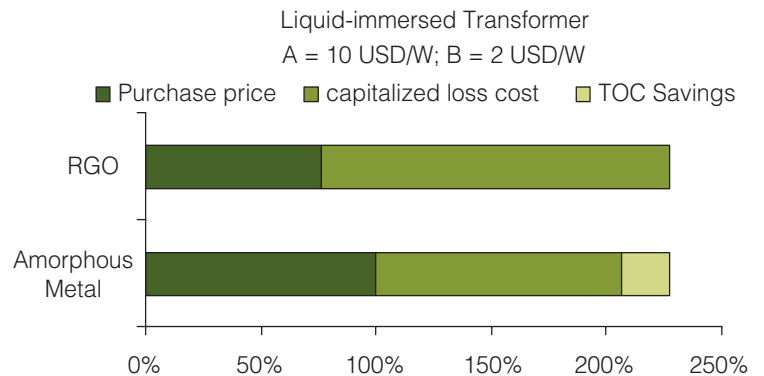
The optimal selection would be the design with the lowest TOC as calculated above. Simply put, the customer/user will obtain a practical balance between investment and reward.

## TOC provides the true economics in evaluating a transformer purchase.

With low loss, high efficiency transformers, the higher material cost typically requires a higher first cost. However, this will be compensated by reduced running costs from lower losses. Beyond a certain time, the lower losses will give a net financial saving from reduced energy costs. If higher loss transformers are replaced with new low loss transformers, this saving becomes even greater. Furthermore, lower losses result in cost avoidance derived from elimination or deferral of extra generation and transmission capacity additions.

## Application example – transformers for utilities

The following figure compares the TOC of liquid-immersed 1,000 kVA transformers having conventional, regular grain oriented (RGO) and AM cores, wherein the loss capitalization factors are:  $A = 10$  USD/W and  $B = 2$  USD/W. The various components comprising the TOC are individually highlighted. Although first costs of amorphous transformers may be slightly higher, they are often the preferred choice if TOC is considered.

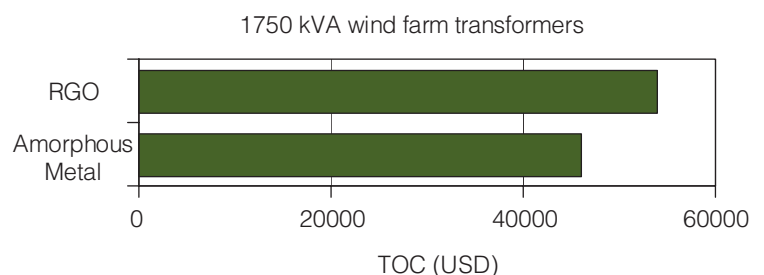


## Application example – transformers in wind farms

Energy is produced from the turbines in a wind farm for only short periods throughout the day. Therefore, it is desirable to minimize no-load losses in wind farm applications.



The advantage of AM transformers in such applications is evident from the figure below. Here, TOC results for 1,750 kVA liquid-immersed, RGO and AM transformers are compared for a wind farm, where  $A = 8$  USD/W and  $B = 2$  USD/W.



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## Amorphous metal – A technological advantage

Amorphous Metal Distribution Transformers (AMDT) from ABB represent the ultra-low loss design solution, delivering the highest efficiencies. They are designed with a unique alloy whose structure of metal atoms occurs in a random pattern and is used in lieu of conventional Regular Grain Oriented (RGO) silicon steel. RGO has an organized grain structure with much higher resistance to magnetization cycles, which leads to higher core losses.

Amorphous metal (AM) enables a significant reduction in no-load losses as compared to RGO, up to 70 percent lower as noted below for representative liquid-filled transformer designs.

Rating (kVA)	No-Load Losses (W) RGO	No-Load Losses AM	Loss Reduction
<b>Single Phase</b>			
15	55	20	64%
25	65	30	54%
50	105	35	67%
75	155	55	65%
100	200	75	63%
167	235	95	60%
<b>Three Phase</b>			
300	505	200	60%
500	725	220	70%
750	1125	355	68%
1500	2170	725	67%
2500	2750	745	73%
<b>Comparison with lowest no-load loss specifications (A<sub>n</sub>) in IEC EN50464-1 with some three phase AM designs</b>			
100	145	75	48%
250	300	110	63%
400	430	170	60%
800	650	330	49%

Studies have also shown benefits from AM in the presence of harmonics or integer multiples of the power frequency (50 or 60 Hz). When non-linear loads (e.g. rotating machines) are present, they cause the current and voltage waveforms to distort, causing harmonics which increase losses in the transformer and reduce power quality. However, these harmonics losses are reduced in an AMDT. This translates into operating savings across a variety of resistive and inductive loads.

The much lower losses of the AMDT result in significant energy and monetary savings over the lifetime of the transformer.

## BIOTEMP® – ABB superior dielectric insulating fluid

BIOTEMP® is a superior dielectric insulating fluid combining environmental friendliness, superior fire resistance and high temperature stability with excellent dielectric characteristics. BIOTEMP® is a natural ester-based fluid made from renewable vegetable-based oil with 99 percent biodegradability. It has a fire point over 300°C and the unique ability to build less tank pressure during high energy arc faults. Its water saturation limit is also much higher than that of mineral oil without affecting its dielectric strength. BIOTEMP® is the most stable vegetable-based dielectric insulating fluid on the market (>75 percent mono-unsaturated fatty acids) outperforming the competition in all standard oxidation stability tests currently available.

Mineral-based oils have been the dielectric insulating medium of choice for transformers for more than 100 years. BIOTEMP® is the ABB alternative solution addressing the major drawbacks of petroleum-based products, i.e., high combustibility and pollution. At the same time, it provides more reliability to your equipment.

### Environmental, safety and operational advantages

- BIOTEMP® is 99 percent biodegradable. Subject to environmental regulations, BIOTEMP® spills can be disposed through normal means and not treated as hazardous waste
- With a fire point above 300°C, BIOTEMP® is listed as a “less flammable” dielectric fluid by FM Global and UL, and has a K2 fire hazard classification (IEC 61100)
- With less pressure build-up during high energy arc faults, BIOTEMP® reduces risk of transformer explosion and fire. It is therefore suitable for indoor applications and outdoor areas of heightened safety sensitivity
- The greater ability of BIOTEMP® to hold moisture allows impregnated paper to experience a much lower aging rate. A BIOTEMP®-filled transformer can consequently operate at higher hotspot temperatures while maintaining the same life expectancy as a standard mineral oil-filled unit, hence increasing its overload capacity

With BIOTEMP®, ABB aims at offering a complete and sustainable solution for transformer applications by combining environmental friendliness (high biodegradability), safety (superior fire resistance) and reliability (high overload capacity).

# ABB has the optimum solution for a greener world

## **ABB's commitment to a greener future – The ABB value proposition**

### **Environmentally friendly – The green distribution transformer program**

Reduce no-load losses 40-70 percent, thus reducing TOC and CO<sub>2</sub> emissions

For each GW saved, annual reduction of five million tons of CO<sub>2</sub> emissions

One 1,000 kVA unit can save seven tons of CO<sub>2</sub> annually

Total solution for high efficiency transformers, new and conventional technologies

### **Reliability, quality, and customized solutions**

Lower losses generate less heat, thus reducing liquid capacity and cooling needs

Tested to exceed applicable standards including short circuit tests

Flexible design tools integrating conventional technology and new solutions in order to optimize a solution based on customers' demand and requirement

Combining the global ABB experience in high tech solutions for conventional technology with new solutions and technologies

Financial advantages based on optimized total ownership cost (TOC)

Due to lower TOC, savings can be realized in as little as three-five years

Lower losses result in cost avoidance derived from elimination or deferral of extra generation and transmission capacity

Increased reliability and longer life time

## **ABB has the optimum solution**

**Amorphous transformers with BIOTEMP® fluid is an environmentally optimized solution**

Amorphous metal lowers ownership cost across entire network from generation to transmission and distribution

Amorphous metal and BIOTEMP® help reduce green house gases along with pollutants

BIOTEMP® is engineered to be environmentally friendly

Offers you the lowest Life Cycle Assessment (LCA) value for a distribution transformer

# Combining energy efficiency, safety and environmental friendliness - ABB has the complete sustainability solution for liquid filled distribution transformers.



## Appendix A

### Calculation of transformer efficiency

When calculating efficiency, one must know the transformer rating ( $kVA_r$ ), loading ( $kVA_l$ ), power factor (PF), and transformer losses. Transformer losses are made up of load ( $P_k$ ) and no-load ( $P_o$ ) losses. Load or winding losses vary directly by the square of the load factor (L), meaning losses increase as transformer loading increases. No-load or core losses remain constant regardless of the load. Furthermore, no-load losses can be a significant percentage of total losses when a transformer is lightly loaded.

$$\eta\% = \frac{L \times kVA_r \times PF \times 10^5}{(L \times kVA_r \times PF \times 10^3) + (TransformerLosses)}$$

$$LoadFactor(L) = \left( \frac{kVA_l}{kVA_r} \right)$$

$$TransformerLosses = P_o + (P_k \times L^2)$$

## Appendix B

### Calculation of total ownership cost (TOC)

In the following, USD is used for illustrative purposes.

$$TOC = C_i + (A \times P_o) + (B \times P_k)$$

where  $C_i$  (USD) is the transformer purchase price, and A and B are the capitalization factors for no-load loss ( $P_o$ ) and load loss ( $P_k$ ), respectively, expressed in (USD/W). There are various methods for calculation of A and B factors. Using a simplified method,

$$A = (12 \times C_d + h \times C_e) \times F_c \quad (\text{USD/W})$$

$$B = C_e \times h \times L^2 \times F_c \quad (\text{USD/W})$$

$$F_c = \frac{(1+i)^n - 1}{i \times (1+i)^n}$$

In these equations,  $C_d$  (USD/W), the demand charge, is the cost for generation capacity extension (utilities) or the monthly rate of peak power (commercial and industrial consumers),  $C_e$  (USD/Wh) is the cost of energy and is customer, application, and standards dependant, h is the annual utilization hours of the transformer (full year = 8760 hours), and  $F_c$  is the present value factor, calculated for n years using a discount rate i.

### Cost of emissions

There currently is no universal way to account for the cost of emissions in TOC as they are very much dependant on the regulatory and political climate. Factors that would be used need to take into account not only economic but also social impact. The latter is most challenging to quantify.

One can account economical costs for emissions within the TOC calculation by adding emission costs ( $C_{em}$ ) to the cost of energy ( $C_e$ ) for a total cost of energy ( $C_E$ ), which takes the place of  $C_e$  in the previous equations.

$$C_E = C_e + C_{em} \quad (\text{USD/Wh})$$

$$C_{em} = E_p \times E_c \quad (\text{USD/Wh})$$

where  $E_p$  (tons/Wh) characterizes total emissions, calculated from the known quantity of emissions for each of the pollutants while producing a certain amount of electricity, and  $E_c$  (USD/ton) is the market value for the pollutants.

ABB recommends a periodic review of the A and B factors. Other factors for such a review would be: the cost of energy ( $C_e$  and  $C_{em}$ ); the effective loading (L); and, the discount rate (i).