

Responding to a changing world

ABB launches new dry-type transformer products

MARTIN CARLEN – Responding to new requirements in a changing world, ABB is complementing its portfolio with new dry-type transformer products that help make electricity supply systems more efficient, reliable, safe and environmentally friendly.

ABB began developing dry-type transformers for medium voltage applications in the 1970s, recognizing that oil-free technologies help transformers comply with the highest safety standards for people, property and the environment. Using dry-type transformers, electric substations can be placed in commercial or industrial buildings without undue concern about fire risk. They are easy to install and maintenance free.

ABB dry-type transformers have evolved into what we now call “standard” dry transformers. They are mostly used to distribute electricity to end users, and are available with different coil technologies:

- Vacuum Cast Coil (VCC): high quality, well-protected windings
- Vacuum Pressure Impregnation (VPI): allows efficient cooling
- Resibloc: ultimate mechanical strength, qualified for extreme climactic conditions (–60 °C)

ABB recently complemented its portfolio with new products that will play a major role in future transmission and distribution (T&D) systems. ABB also offers a broad portfolio of specialty products for many, often specialist, applications → 1.

Customer interest in products that are both economically and ecologically efficient inspired ABB to develop a dry-type transformer product family that exceeds expectations in these areas.

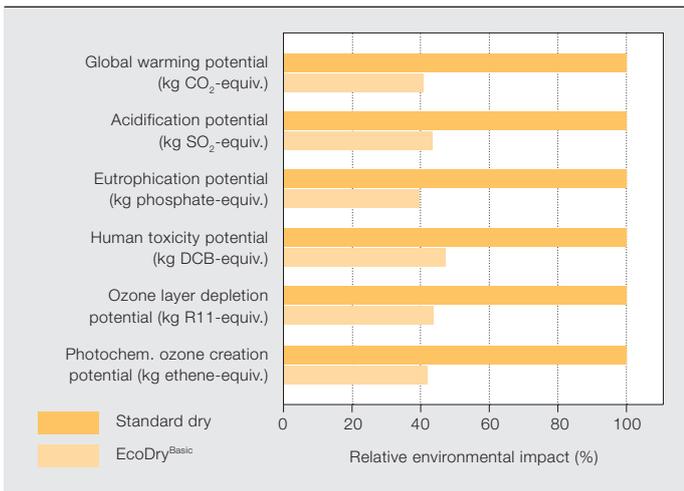
Efficiency, space and reliability counts

Customer interest in products that are both economically and ecologically efficient inspired ABB to develop a dry-type transformer product family that exceeds expectations in these areas. The EcoDry transformer family provides ultra-efficient products with loss values that easily meet or exceed industry standards or legal requirements. EcoDry enables customers to select a product optimized for a specific

1 Additional dry-type transformer and reactor products

- Rectifier and converter transformers
- Transformers for marine applications
- Transformers for wind turbines
- Air-core reactors
- Iron-core reactors
- Transformers and reactors for rolling stock

3 Life cycle analysis performed for a standard dry transformer and an EcoDry transformer (1,000 kVA, 20 percent load) (see ABB Review 2012/2, p.46)



application, minimizing the cost of related investments.

Transformer losses occur in two areas: first, the load independent no-load loss, which occurs in the iron core due to the cyclic change of magnetization resulting from the connected AC voltage; and secondly, the load loss, which depends on the electrical resistance in the transformer windings and on the actual transformer current. Overall, this produces an efficiency curve that is load dependent. When the transformer load is low, the no-load loss will dominate, whereas at high load, the load loss is dominant. Analysis of the total ownership cost [2] will help in the selection process → 2.

EcoDry^{Basic} substantially reduces no-load loss with a core made of amorphous metal. The no-load loss of the EcoDry^{Basic} is 30 percent that of the no-load loss in dry-type transformers fitted with normal steel laminate cores. And these savings add up: when a small, 1,000 kVA dry-type transformer is operated for 20 years, CO₂ emissions are reduced by 140,000 kg, which is equivalent to burning 60,000 liters of oil. Utility distribution transformers often operate at a rather

low average load of 20 percent [1]. EcoDry^{Basic} has lower losses than low-loss, oil-immersed distribution transformers.

In industrial processes, transformers frequently run at nearly maximum capacity. In its EcoDry^{99Plus} transformer, ABB has developed design enhancements that reduce transformer losses by 30 percent or more.

EcoDry^{Ultra} combines features, reducing both no-load and load loss, and providing ultimate efficiency over the whole load range. In the event of strongly varying loads, for example in solar and wind power generating applications, or for operating the transformer at medium load, EcoDry^{Ultra} is the ultimate choice.

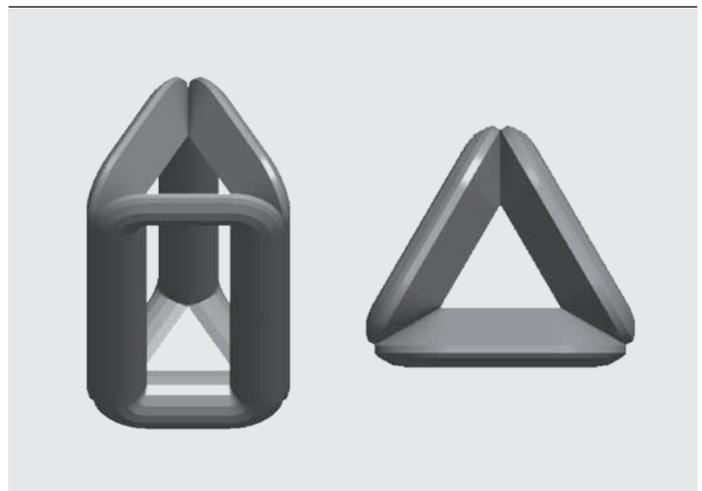
Although EcoDry transformers require more materials in construction, energy savings over the equipment's lifetime more than compensates for this, and makes this product a winning solution environmentally, as demonstrated by life cycle assessment (LCA) [2] → 3.

Another way to increase transformer excellence that also enables compact installations and reduced losses is with the

2 Comparison of TOC (total ownership cost) of standard and EcoDry amorphous metal core transformers (see ABB Review 2012/2, p.47)



4 A triangular wound core which consists of three identical core rings. Left: perspective model. Right: model seen from above.



5 TriDry configuration reduces weight and footprint.

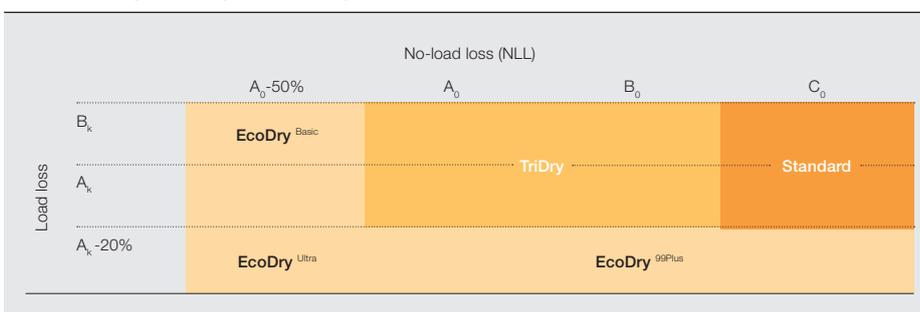


The core of a TriDry transformer is wound from a continuous strip of magnetic steel without any joints, therefore avoiding the related losses.

6 Characteristics and ratings of ABB dry-type distribution transformers

Standard dry transformer	TriDry	EcoDry
Well proven and highest reliability	Compact, efficient, safe	Ultra-efficient transformer
Core: Stacked core, 3-leg	Core: Triangular, continuously wound core	Core: Amorphous 3-leg Evans cores, or stacked core
Coils: VCC, VPI or Resibloc round, rectangular or oval	Coils: VCC round	Coils: VCC, Resibloc rectangular
Voltage: 0.1–40.5 kV	Voltage: 1.1–36 kV	Voltage: 1.1–36 kV
Power: 5–40,000 kVA	Power: 100–2,500 kVA	Power: 100–4,000 kVA
Special characteristics: Well-established and proven	Special technical characteristics: symmetrical transformer	Special technical characteristics: Amorphous core
Benefits: Non-flammable and self-extinguishing No maintenance High short-circuit strength Easy installation Low-loss designs possible	Benefits: Low loss Different and compact footprint Low magnetic stray fields Note: Some products may not be available globally.	Benefits: Minimum losses most interesting solution in case of medium or high electricity costs Environmentally beneficial

7 Loss classes according to EN 50541-1 and positioning of TriDry and EcoDry product families



TriDry transformer. This small revolution in transformer technology uses a triangular core configuration which restores the symmetry of three-phase AC systems. Similar to a generator or motor where the poles are arranged in a circular configuration, TriDry phases also have a circular arrangement → 4. This differs from conventional transformers with a planar layout, where the phases arranged side by side result in differences between middle and outer phases, incomplete utilization of core material, and other deficiencies.

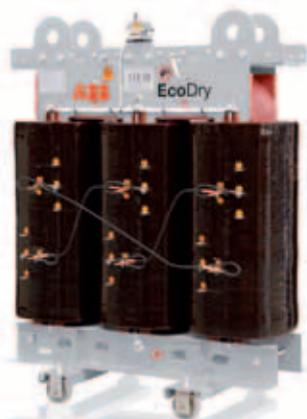
The core of a TriDry transformer is wound from a continuous strip of magnetic steel without any joints, therefore avoiding the related losses. The width of the steel sheet varies in order to produce an almost D-shaped cross section of a core ring. Three core rings of almost rectangular shape are mounted together to form a three-phase core with triangular shape. Each core leg is made up of two D-shaped parts from two core rings combined, resulting in a circular cross section. Since the core cannot be opened, the windings are directly wound onto the core and vacuum casting is also done directly onto the core.

In this symmetrical, triangular set-up, each of the three core legs is linked directly to the other two, and feature symmetrical and short distances for the magnetic flux. In addition to the usual rectangular path via the core rings, the flow of flux is also possible via the triangular arrangement of yokes. If the magnetic flux in the yoke sections of one of the core rings becomes too large and the yoke saturates, the flux can pass through the other two core rings, amounting to a flux through the three yokes arranged in a triangle.

The TriDry triangular configuration enables compact installation with a reduced footprint and up to 20 percent less weight → 5. The symmetry of the technology results in transformers of the highest reliability, reduced in-rush current, reduced sound levels, reduced magnetic stray fields and reduced losses → 6.

Standards for losses or minimum efficiency values for transformers are different in different countries. China is well advanced by having defined different efficiency classes, including standards for amorphous transformers, for a number of years. In Europe, different loss classes for dry-type transformers have been introduced only recent-

8 EcoDry amorphous transformers provide ultimate efficiency over the whole load range.



ly, with the launch of EN 50541-1. Note that the losses of the EcoDry amorphous transformer are half those of the best loss classes specified by EN50541-1 → 7-8.

Going overhead

Overhead distribution is common in many countries and in rural areas. It is an easy and fast way to set up an electricity distribution grid and provide power to consumers. Transformers, for stepping down the voltage used in overhead power lines to the level needed by customers, are directly mounted on the poles.

Traditionally, pole-mounted transformers are oil-immersed units. The oil makes very good insulation, but presents environmental and safety risks. If the transformer tank ruptures or leaks due to an internal failure or external damage, the liquid will run out and contaminate the ground. This is especially problematic in protected water areas, in rivers and lakes, or public and national parks. In addition, leaking transformers will also soon stop working.

In some countries, the theft of copper or oil from pole-mounted transformers is an important issue. Electric utilities not only have to replace the damaged units, but also clean up and dispose of the oil-contaminated ground, which is often much more expensive than replacing the transformer itself. And the risk related to inflammable oil is an issue, especially in residential and forested areas.

To eliminate these problems, ABB developed PoleDry, a dry-type transformer for pole-mount applications → 9, 10. It is non-

9 PoleDry is a dry-type transformer for pole-mount applications.



flammable, does not need an enclosure, and is comparable in size and weight to oil-immersed transformers. Due to its cast aluminum windings, it is also not a target for theft.

Creating the PoleDry transformer required some special considerations. Eliminating the air gap between the primary and secondary windings, which is typical of dry-type transformers, removed the risk of contamination or ingress of animals between coils, and is very important for ensuring high reliability in an outdoor transformer. PoleDry is therefore manufactured with solid insulation between the windings, and utilizes hydrophobic cycloaliphatic epoxy (HCEP) to encapsulate the windings. This epoxy provides superior outdoor performance in other applications, and is also outstanding in terms of resisting fire, UV rays, erosion and external tracking. Bushings are cast together with the windings, and are fully integrated to prevent any water penetration. Simulations and experimental tests were done to control the electric fields, optimize the design and avoid any tracking on the surface. A final important feature is the core's special corrosion protection.

PoleDry has been tested in the harsh outdoor environment of ESKOM's Koeberg Insulator Pollution Test Station (KIPTS) in Cape Town, South Africa. KIPTS is close (30 meters) to the sea, which provides an environment that includes plenty of exposure to UV, rain, wind and sand erosion, industrial pollution, salt-laden moisture, and wildlife → 10. Coils and cores were tested in a salt-fog chamber, which allows

10 Characteristics and ratings of PoleDry transformer and outdoor testing at KIPTS



Ultimate safety in overhead distribution

Core:	Stacked core, 3-leg
Coils*:	VCC, with cycloaliphatic outdoor epoxy
Voltage:	1.1-24 kV
Power:	50-315 kVA, 3-phase

Special technical characteristics:
No air-gap between primary and secondary coil
Integrated bushings
Corrosion resistant core protection

Benefits: Dry-type transformer for pole-mount application with size and weight comparable to oil-filled unit; environmentally friendly; unattractive for copper theft

Dry-type transformers are easily installed in buildings or underground, and do not require costly additional protective equipment or other infrastructures.

controlled and accelerated cycling between phases with salt fog, clean fog and UV radiation up to 50 times as intense as natural UV radiation [4]. The first 20 commercial units, three-phase transformers with a 100kVA power rating and with 15 or 20kV primary voltage, are destined for the Italian utility, ENEL.

Going underground

An opposite approach was necessary for the submersible transformer. This unit is suitable for underground installations, in vaults or subways which are occasionally, or frequently, flooded with water → 11.

An example of submersible transformer installations is the network transformers used in the city of New York (NYC). These three-phase transformers with power ratings of 500 to 2,500 kVA are connected to a network protector, and serve loads in New York's downtown. They are typically placed in vaults under grates in the sidewalks. In the event of heavy rain the vaults, which do not have drainage systems, can become partially or fully flooded. In addition, all surface debris washed off from the streets ends up in the vaults.

In traditional oil-immersed network transformers, internal faults or short circuits can lead to large, street-level explosions and fires, which can cause significant harm to people and property. For this reason Consolidated Edison (ConEd), the electric utility in New York, approached ABB and asked for a dry version of these transformers. Pilot dry network transformers have now been in operation since the middle of 2011.

An important prerequisite was the dry transformers had to fit the dimensions of the existing vault dimensions. They also had to contain a grounding switch integrated with the VCC transformer in a robust tank. This enables easy grounding in case the network requires maintenance work. The dry transformer itself is maintenance free, and is designed to be low sound emitting for urban environments. Multiple arc-fault testing was required by ConEd in order to prove the unit's safety.

Feeding power-hungry cities

A burning transformer in an urban area, producing smoke and fumes and widely visible to the public is a nightmare scenario for T&D operators. Although the

11 Submersible dry-type transformer for network application



Safety for environment and people	
Core:	Stacked core, 3-leg
Coils*:	VCC, high temperature insulation system
Voltage:	1.1–17.5 kV
Power:	100–1,000 kVA
Special technical characteristics:	
Mounted in completely sealed enclosure	
Low sound level	
Benefits: Transformer installation can be flooded	
Non-flammable and self extinguishing	
Applicable as network transformer	
No risk of oil spills	

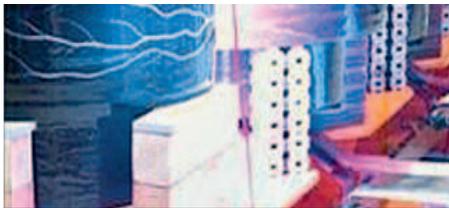
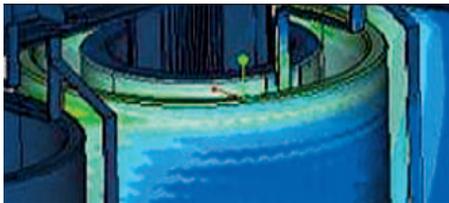
risk of any piece of electrical equipment failing can never be completely excluded, the consequence of such a failure may be heavily dependent on the technology used. With new dry-type transformers, it is possible to minimize the consequences of such occurrences.

Voltage classes for dry-type transformers typically range up to 36kV, and their application is mainly in the distribution grid. Following intensive research, ABB has introduced HiDry⁷², a dry-type transformer for the 72.5kV voltage class. This means dry-type transformers are now available for sub-transmission voltage levels → 12, 13. Urbanization and the rapid growth of megacities requires more and more power in downtown areas, and using higher voltages to deliver it is beneficial.

Dry-type transformers are easily installed in buildings or underground, and do not require costly additional protective equipment or other infrastructures, such as oil pits, etc. Since vacant space in big cities is limited and expensive, these types of transformers not only provide optimized performance, but also an improved appearance.

A number of new concepts had to be introduced in order to produce a dry transformer at this voltage level, including

12 Electric field intensity in a 10 MVA, 72.5 kVA dry-type transformer and testing



3D simulation of the electric field intensity in a 10 MVA 72.5 kV dry-type transformer and dielectric testing of the transformer beyond the limit

It is now possible to use dry-type transformers in certain applications for the very first time, thanks to ABB innovations that have increased energy efficiency and made higher voltages possible in compact outdoor and submersible installations.

shielding rings in the windings; conductive shielding pieces for the clamps and magnetic yokes; rounded corners in windings and shields; and an optimized number of barriers and barrier arrangements to control the electric field in the insulating air. The combination of numerical simulations and experimental testing on model devices and full-size prototype transformers helped ABB create competitive designs → 12.

72.5 kV dry-type transformers require a footprint similar to oil transformers. While cooling equipment and radiators in oil transformers require considerable space, dry-type transformer coils are

13 Characteristics and ratings of ABB's HiDry transformer for subtransmission

HiDry	
Getting power into cities	
Core:	Stacked core, 3-leg
Coils*:	VCC, Resibloc
Voltage:	40.5–72.5 kV
Power:	1,000–63,000 kVA
Special technical characteristics: Dry-type transformer for sub-transmission (72.5 kV voltage class)	
Benefits: Inner-city and underground installation Water protection and fire risk areas oil & gas and industrial applications	

directly cooled by air. The higher temperature rise of the dry-type transformer makes cooling more efficient due to a higher temperature gradient and increased radiative cooling at higher temperatures.

However, since dry technology requires larger dielectric clearance distances, the core and therefore also the mass of the dry-type transformer is slightly larger, which also results in a somewhat increased no-load loss. The load loss is comparable to the load loss of an oil transformer, so total losses are only slightly larger with a dry-type transformer → 13.

HiDry⁷² transformers can be provided with an on-load tap changer. They have high short-circuit strength, thanks to strong reinforcement of the coils by the solid insulation material and their cylindrical geometry.

They are suitable for substation retrofits, or for new installations, and paralleling with existing oil transformers is possible. Besides inner city and underground substations, HiDry⁷² is a perfect choice for power plant applications, substations in or close to buildings, in caverns or in protected water areas, and industrial applications such as chemical plants or oil and gas installations. For example, two HiDry⁷² transformers rated 25 megavolt ampere (MVA), 66/13.8–11.9 kV with on-load tap changers will be installed in the new Estádio Fonte Nova in Salvador, Bahia, Brazil, which is one of the stadiums hosting the 2014 FIFA Soccer World Cup.

14 Success story: power reliability for the world's tallest building

When it was completed in January 2010, Burj Khalifa in Dubai became the world's tallest building with 164 floors and a total height of 828 meters. To ensure power reliability throughout the enormous building, it is equipped with 78 ABB dry-type transformers, which are renowned for their mechanical strength and reliability → picture 4 page 9.

The nearby Dubai Fountain, which is illuminated by 6,600 lights and shoots water 150 meters into the air, is also equipped with ABB transformers. It is the world's largest fountain.

The launch of ABB's new dry-type transformer products addresses an important need for safe and environmentally-friendly power products usable in a variety of applications, including urban settings and environmentally sensitive areas → 14. It is now possible to use dry-type transformers in certain applications for the very first time, thanks to ABB innovations that have increased energy efficiency and made higher voltages possible in compact outdoor and submersible installations.

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