ABB Transformers

EcoDry
The highest-efficiency dry-type transformers
Distribution transformers from ABB

- ABB is globally the leading transformer manufacturer in both Power and Distribution area
- ABB is committed to develop all its products to meet the ever more demanding environmental and efficiency requirements
- ABB offers a complete portfolio of distribution transformers fitting any customer need, specification requirement and demand including a green transformer program
  - Liquid filled distribution transformers
  - Dry-type transformers

In this presentation we focus on dry-type transformers
Presentation overview

- How can transformers reduce CO$_2$ emissions
- Dry type transformers portfolio
- Transformer losses and EcoDry transformers
- Capitalization of losses
- EcoDry: the Economics and the Environment
- ABB’s commitment to a greener future
Introduction threat
Our every day necessities…

- Ever-growing population
- Energy consumption to double within 30 years
- Sustaining a power-hungry world
- Concern about climate change
- Ensuring a reliable grid
- Providing energy efficient products and solutions
- Investing in the future

More than ever, the need for energy efficient products and reliable grids will grow. ABB’s transformers support the systems that keep our world running.
Reducing transformer losses by 70%?
Act now and contribute to a better life and society!

*based on HD538 Norm

- With ABB, you can reduce transformer losses by 70%*
  - the environment will benefit
  - you get a financial attractive solution
  - profit from all the benefits of dry transformers
CO₂ emissions - the major climate threat
Distribution transformers can help reduce CO₂

An EU study* concludes:
- in EU-27 there are 4.5 million distribution transformers
- producing 38 TWh/year of losses – more than the total electricity consumption of Denmark, which is equivalent to 30 million tons of CO₂
- cutting losses of distribution transformer by more than 50% is possible

This also means
- Annual avoided CO₂ costs of 400 MEUR (€25/t CO₂)
- Reduced need by 5 GW in power generation capacity (=7 BEUR investment)

*SEEDT – Strategies for development and diffusion of Energy Efficient Distribution Transformers;
Dry-type transformers
Dry-type transformers
The widest technology available

- Unique manufacturer with three technologies:
  - Vacuum cast coil
  - RESIBLOC®
  - Open Wound

- Complementing technologies dedicated to specific market demands
- More than 35 years experience
- Proprietary technology and R&D departments
Dry-type transformers
The widest product portfolio cont’d

- Power and voltage range
  - From 50 kVA to 63 MVA
  - Up to 72.5 kV
- On Load Tap Changers available
- UL certified transformers
- Unique Class “H” Vacuum Cast Coil transformers producer certified
- Low Loss and high efficiency
- Transformers for any special application (Marine, rectifiers, mines, traction, etc.)
- Providing any type of enclosure, incl. different means of cooling
Dry-type transformers
Applications

Public Works and Utilities
- Hospitals
- Airports
- Shopping centers
- Public buildings
- Office buildings
- Stadiums

Special Industries
- Chemicals, Oil and Gas
- Mining industry
- Applications with variable speed drives or rectifiers
- Automotive
- Data centers

Transportation
- Ships
- Metro systems/ trains
- Tunnels

Power Generation
- Power Plants
- Wind power
- Solar power
Dry-type transformers
…power the biggest and tallest buildings of the world

- **Burj Khalifa, Dubai**: 828m
  - 72 transformers
  - 750 – 2’000 kVA, 11/0.4 kV

- **Shanghai World Financial Center**: 492 m
  - 3 transformers
  - 12’500 kVA, 35/10.5 kV
Dry-type transformers
Main advantages of dry-type transformers

- Safety for people and property
- Ecological and environmentally friendly
- Maintenance and pollution-free solution
- No fire hazard
- Easy installation
- Excellent resistance to short circuit currents
- Excellent capacity to support overloads
- Excellent performance in case of seismic events
- Suited for damp and / or contaminated areas
- Reduced cost on civil installation works and fire protection systems
...is now complemented by the highest-efficiency EcoDry transformer

- With no-load loss at 35% of standard dry-type transformers
- Product range: 100-4,000 kVA; up to 36 kV
  other ratings on request
- Without or with all types of enclosures
EcoDry …

- Is a high-tech product based on more than 2 decades of continuous developments
- Applying simulation tools for loss-optimized design,
- Using most-advanced materials and high quality components
- Amorphous metal as core material being one of them
- Amorphous metal has proven its reliability in oil-filled distribution transformers being in service for > 20 years
- Ratings from few kVA to several MVA are possible
- Uses the proven basic design concepts of conventional transformers
Transformer losses and EcoDry transformers
Our value proposition
EcoDry – the ultra-efficient dry-type transformer

- EcoDry is ABB's product family of ultra-efficient dry-type transformers
- Eco-friendly, energy-saving and safe
- Optimized to suit the specific load profile of an application:
  - EcoDry$^{\text{Basic}}$ for low average load - reduction of no-load losses by 70%
  - EcoDry$^{\text{Ultra}}$ for medium or strongly varying load - reduction of total losses by 45%
  - EcoDry$^{99\text{Plus}}$ for high average load - reduction of load losses by 30%
Transformer no-load losses and load losses
Iron and copper loss

- No-load losses are caused by the alternating magnetization of the core (hysteresis loss) and by eddy-currents in the core – they occur as soon as a transformer is energized.

- Load losses are caused by losses in the conductors (resistive and eddy current) – they have a quadratic dependence on the load factor.

- Depending on the characteristic load profile related to your applications, either the no-load losses, the load losses, or both should be minimized.
Transformer no-load losses and load losses
Transformer load und EcoDry transformers

EcoDry\textsuperscript{Basic} for low average load, this is often the case for utility distribution
EcoDry\textsuperscript{Ultra} for medium load or strongly varying load, e.g. renewable energy
EcoDry\textsuperscript{99Plus} for large average load, this is often the case in industry applications

No-load losses $= 4 \times$ load losses
Load losses $= 4 \times$ no-load losses

Load losses $P_k$
No-load losses $P_0$
EcoDry: highest-efficiency transformers for your application
EcoDry
The green evolution in transformer technology

- Energy efficient
- Environmentally friendly
- Cost beneficial
- Solves your problems
EcoDry Basic
Up to 70% lower loss

⇒ In utilities reduction of no-load loss has major focus as average loading typically is on a relative low level due to considerations for reliability of supply

- EcoDry basic is optimized on reduction of no-load losses
- It combines a major reduction in no-load loss with an optimized design for load loss allowing a loss reduction of up to 70%*

*based on HD538 Norm
EcoDry\textsuperscript{99Plus}
Field proven dependability with high efficiency

- Focus on energy intensive applications
- Reduction of load loss – above 99% operation efficiency; up to 32% less energy consumption
- Amortization of additional first cost within 1 year possible; lifetime savings can equal or exceed investment costs
- Increasing cost for energy and CO\textsubscript{2} further reduces amortization time
EcoDry\textsuperscript{Ultra}

The ultimate solution for transformer loss reduction

- Combines the advantages of EcoDry\textsuperscript{Basic} and EcoDry\textsuperscript{99Plus}, by simultaneously minimizing no-load and load loss
- Best suited for applications with constant load and redundant supply from two transformers, like e.g. for pumping or ventilation
- For applications with strongly varying load, as for renewable energies, like photovoltaic and wind power
- EcoDry\textsuperscript{Ultra} guarantees a maximum generation output, while minimizing loading the grid due to the no-load losses during periods of shadowing or wind lull
Capitalization of losses
Capitalization of losses
Calculating Total Ownership Costs

Total Ownership Cost (TOC) method takes future operating cost of a unit over its lifetime brought back into present day cost to be added to its purchase price to arrive at TOC

\[
\text{TOC} = \text{Price} + [A \ (\$/W) \times \text{No-load losses (W)}] + [B \ (\$/W) \times \text{Load losses (W)}]
\]

Optimising a design using A and B factors results in the most cost-effective design over the transformer life cycle, based on customer’s cost of energy and load factors:

- Cost of capital
- Cost of energy
- Cost of additional capacity – generation, transmission & distribution
- Transformer Operating hours per year
- Loading Characteristics – peak & load factor

TOC provides true Economics lower losses result in a cost avoidance derived from the elimination or deferral of generation and T&D capacity additions
Capitalization of no-load losses and load losses

- **A-factor for no-load losses:**
  \[
  A = (8760 \times C_e + 12 \times C_d) \times F_c
  \]
  
  \(C_e\): energy costs  
  \(C_d\): monthly rate peak power

- **B-factor for load losses:**
  \[
  B = C_e \times h \times \left( \frac{S_L}{S_r} \right)^2 \times F_c
  \]
  
  \(h\): annual utilization (hours)  
  \(S_L\): effective load  
  \(S_r\): rated power

- **Formula for discount factor:**
  \[
  F_c = \frac{(1+i)^n - 1}{i \times (1+i)^n}
  \]
  
  \(i\): discount rate  
  \(n\): years

Example: \(C_e=0.1\ USD/kWh, C_d=8\ USD/kW/month, h=5000\ h\ (55\%), i=8\%, n=15\ yrs,\)
\(F_c=8.56\Rightarrow A=8.3\ USD/W\ )  
(For average load of 40\%: B=1.29\ USD/W)
TOC dependence on A-factor

EcoDry has higher initial costs, but for A-factors > ~5 USD/W in a TOC perspective EcoDry is becoming the right choice.

Remember: quantifies the avoided costs of the no-load loss (incl. energy costs, power costs, capitalization factor)
Highest-efficiency transformers give additional benefits

- Lower investment costs in cooling infrastructure
due to lower total losses of transformer and cables: 30-50% lower rating

- Reduced energy consumption for operation of cooling
  by fan only, 20 years: 1,500 W_th, electric/thermal: 10%=150 W
  by AC, 20 years: 1,500 W_th, electric/thermal: 30%=450 W

- And other potential savings
  - Insurance premier
  - Building cost
  - Service and spare part cost
  - Logistic and transportation

- … and the related reductions of CO₂ emission:
  140’000 kg CO₂ for 1’000 kVA transformer within 20 years
  - equivalent to 60’000 liter of oil -
Comparison of losses

1'000 kVA / 20 kV
Dry-type transformers

No-load losses

- Standard dry-type
- EcoDry\textsuperscript{Basic}
- EcoDry\textsuperscript{Ultra}
- EcoDry\textsuperscript{99Plus}

Load losses

- Standard dry-type
- EcoDry\textsuperscript{Basic}
- EcoDry\textsuperscript{Ultra}
- EcoDry\textsuperscript{99Plus}
EcoDry\textsuperscript{Basic} – the two E\text{`}$s: Economics and Environment Economics

TOC – Total Ownership Costs

- A = 6 USD/W; B = 0.5 USD/W
  
  - Standard dry-type
  - EcoDry\textsuperscript{Basic}

- A = 12 USD/W; B = 2 USD/W
  
  - Standard dry-type
  - EcoDry\textsuperscript{Basic}
EcoDry<sup>Basic</sup> – the two E‘s: Economics and Environment

Environment: LCA – Life Cycle Assessment

- Although a EcoDry<sup>Basic</sup> transformer needs more raw materials than a standard transformer, the LCA-analysis shows, that its overall environmental impact is much lower.
Market and environmental drivers
ABB response

Drivers
- CO₂ emission and global warming

Global trends and results
- Focus on energy efficiency and low loss transformers
- New standards, requirements and evaluation criteria
- Interests in new solutions / technologies

Local trends
- Energy saving targets
- Interest in new solution / technologies
- Loss capitalization guidelines

ABB response
- Extensive global R&D in transformers
- Absorbing global trends
- Evaluating different technologies / solutions
- Design and production of highly reliable products
- High flexibility design tools for optimization and customization of products
- ABB is dedicated to develop and contribute to reducing CO₂ emissions and decreasing global warming effects in our processes and products

We are ready to be your partner
for future requirements, sharing our global know how and R&D expertise for a “greener world”
Amorphous metal
Amorphous metal
A high tech material

- Amorphous metal (AM) is produced by rapid solidification from the liquid
  - Cooling rates ~ $10^6$ K/s
  - Result: Thin material (~ 25 µm)
  - Production rate ~ 100 km/h

- AM structure is a snapshot of the disordered liquid structure at the moment of solidification
  - Conventional transformer steel (e-steel) has an ordered crystalline structure

- AM is a Fe-Si-B metallic alloy; e-steel is a Fe-Si alloy

- AM is very ductile as-cast, but becomes brittle upon required anneal
  - Magnetic field applied during anneal to optimize properties
  - Today’s annealed material is easier to handle than before, due to chemistry and anneal condition modifications
Amorphous metal in distribution transformers
Material characteristics

- Lack of crystal structure \(\Rightarrow\) easier and faster magnetization
  - Result: Significantly reduced core losses (reduced by 40 - 70%)

- Lower Saturation Induction than e-steel, due to presence of non magnetic boron
  - Design Induction restricted to \(~1.35~T\)
  - CGO designs could go up to 1.8 T

- Noise levels in AM DTs are 3 – 5 dB higher than in e-steel DTs, but are below the noise level specifications in global standards
  - Higher noise levels are due to the lack of crystalline structure

- Utility studies on AM DTs over the last two decades have shown no degradation of performance over time
AMDT active part assembly process
Extensive ABB expertise in wound core DT technology

- Similar technology as used for wound core distribution transformers
- Distributed gap (step-lap) core
- Joints opened, core inserted into coils, and the core laced back at the joints
Summary
EcoDry
Customer’s benefit (1/2)

- Environmentally friendly – EcoDry family
  - Reduce no-load losses up to 70%, thus reducing TOC and CO₂ emissions
  - For each GW saved, annual reduction of 5 million tons of CO₂ emissions
    - 1 unit 1’000 kVA saves 7 tons of CO₂ annually
  - Total solution for high efficiency transformers, new and conventional technologies

- Reliability, quality and customized solutions - I
  - Lower losses generate less heat thus reducing aging of the insulation
  - Tested to exceed applicable standards including short circuit tests
EcoDry
Customer’s benefit (2/2)

- **Reliability, quality and customized solutions - II**
  - Flexible design tools integrate conventional technology and new solutions in order to optimize a solution based on customers’ demand and requirement
  - Combining the global ABB experience on high tech solutions for conventional technology with new solutions and technologies

- **Financial advantages based on optimized TOC**
  - Due to lower TOC, savings can be realized in as little as three years
  - Lower losses result in cost avoidance derived from elimination or deferral of extra generation and transmission capacity
  - Increased reliability and longer life time
EcoDry
The green evolution in transformer technology

- Energy efficient
- Environmentally friendly
- Cost beneficial
- Solves your problems

Product range:
100-4’000 kVA, up to 36 kV
Power and productivity for a better world™