Dry-type transformers
A solution for any of your needs
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- Innovations in Dry transformers
  1. HiDry\textsuperscript{72}: dry solution for subtransmision lines
  2. EcoDry: the ultra-efficient dry transformer
  3. TriDry: compact – efficient – safe

- Dry transformers for VSD applications
HiDry\textsuperscript{72} for sub-transmission lines
HiDry72
The range

- Ratings from 250 kVA to 63 MVA
- Primary voltage up to 72.5 kV:
  - 325 kV BIL / AC 140 kV according to IEC
- Secondary voltage up to 36 kV:
- With or without on-load tap changer (OLTC)
- Classes: E2, C2, F1
- Partial discharges: <10 pC
- Insulation: 155 °C (F), 180 °C (H)
- AN, ANAF (up to +30%), AFWF
- Design temperature: 40 °C
- Star or delta connection
- Up to 17 taps with ±10% regulation range
- Options, enclosure IP21 up to IP54
HiDry72
Advantages and benefits

For retrofit or new installations
- Similar footprint as existing transformers, when IP00 and NOLT
- For indoor or outdoor installation
- Paralleling with existing oil-transformers possible

Safe and environment friendly
- No flammable liquids. Self-extinguishing solid insulation
- 10-20 times smaller combustible mass, minimum smoke
- No risk of explosion
- Lower insurance liabilities

Environmentally-friendly and cost-efficient
- Optimized load loss
- Lower infrastructural cost. Simple installation, no special civil works
- Minimal requirements for safety and protection installations
- Virtually maintenance free
- Easier unload and more efficient logistic costs
HiDry™
Applications areas

- Inner-city substations
- Indoor and underground substations
- Chemical, oil and gas industry
- Environmentally sensitive areas (e.g. water protection areas)
- Renewable generation (e.g. off-shore wind turbines)
- Fire-risk areas (e.g. forests)
The 72.5 kV series transformer design is very demanding and requires special solutions:

- Strengthened and high quality insulation
- Special HV terminals
- Control of electric fields
- Rounded components and use of shields
- Adjusted dielectric distances
- Special supports to increase the creepage distance and avoid leakage currents.

Development strongly supported by ABB Corporate Research and University collaborations.

Extensive use of computer simulations allowed fast development and product optimization.
72.5 kV dry-type transformer
On-load tap changer

Characteristics of OLTC:

- Dry, oil-free technology
- Linear type
- Current design
  - For up to 17 positions and ±10% regulation (*)
  - Max voltage step 900V
  - Max current 500A
- > 100’000 operations
- Low maintenance
- Installation
  - Indoors: Polution level II
  - Outdoors: IPX4D
- Increases transformer width due to higher clearances in air

(*) presently limited availability, please contact us for clarification
Success story in 2012
Spain, ABB PS, REE (Flywheel PowerCorp)

Customer need
- 1 x 1800 kVA, 66 / 0.44 kV NOLTC, step-up

ABB response
- Dry VCC trafo for PCS100 application
- Installation outdoors IPX4D, in Lanzarote Island

Customer benefits
- Voltage and frequency stability compensator for grid
- Fire hazard
- Environmental and ecological
Success story in 2012
Brasil, ABB PS, Coelba, Fonte Nova Stadium-Salvador

Customer need
- 2 x 25000 kVA, 69 / 13.8-11.9 kV OLTC (+8 x 1.25%) for main substation

ABB response
- Dry VCC transformers for main substation (head)
- An innovating and improved solution

Customer benefits
- Safety for people and fire hazard
- Environmental and ecological
- Savings in the installation and operation
HiDry\textsuperscript{72}

Summary

- ABB, 1\textsuperscript{st} supplier in dry technology AN for 72kV level
- Available OLTC in 72kV
- Safe, environmentally-friendly and cost-efficient solution
- Strongly recommended for urban or underground substations, power plants and new installations in industry
- Complete TOC for decision of investment
EcoDry
Ultra efficient dry transformers
Transformer no-load losses and load losses
Transformer load und EcoDry transformers

No-load losses = 4 x load losses
Load losses = 4 x no-load losses

Loses

Load losses $P_k$
No-load losses $P_0$

0% 20% 40% 60% 80% 100%
Load

**EcoDry**$^\text{Basic}$
for low average load,
this is often the case for
utility distribution

**EcoDry**$^\text{Ultra}$
for medium load or
strongly varying load,
e.g. renewable energy

**EcoDry**$^\text{99Plus}$
for large average load,
this is often the case in
industry applications
EcoDry: highest-efficiency transformers for your application

1'000 kVA reference case

- EcoDryBasic
- EcoDryUltra
- EcoDry99Plus
- Standard dry-type

No-load losses

Load losses

EcoDryBasic
EcoDryUltra
EcoDry99Plus
Comparison of losses

1'000 kVA / 20 kV
Dry-type transformers

No-load losses

<table>
<thead>
<tr>
<th>Model</th>
<th>No-load losses (W)</th>
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<tbody>
<tr>
<td>Standard dry-type</td>
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Load losses

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EcoDry and the new EN 50541-1 Norm
Losses and sound level for dry trafos up 3.150 kVA

- The combination C0Bk is the previous for standard transformers.
- The Non-Load losses for EcoDry\textsuperscript{Basic} and EcoDry\textsuperscript{Ultra} are by half of A0
- The Load losses for EcoDry\textsuperscript{99Plus} and EcoDry\textsuperscript{Ultra} are significatively below Ak
- The TriDry shows an efficiency according to class B0Bk
EcoDry
Summary

- New trends of efficient transformers worldwide (ie. EN 50541-1)

- Amorphous transformers the highest recommendation for very low loading factors (ie. utilities)

- Mainly for industry segment the best recommendation is the 99plus family, with standard grain oriented magnetic core.

- For the right decision of the investment, it is necessary to perform the TOC and turn of investment analysis.
TriDry
Compact, efficient and safe
TriDry Transformer
The range

Standards:
- IEC60076-11: 2004

Product Scope:
- Ratings: 400 kVA up to 1600 kVA
- Voltage levels: 10 kV up to 24 kV

 Ambient:
- Indoor, -25°C up to +40°C
- Insulation Class: F
TriDry Transformer: compact I
Compact with a highly efficient core

- Wound core technology, continuously wound, without air-gaps, reducing the magnetic reluctance of the core
- A symmetrical, three-phase magnetic circuit
- Optimized utilization of the core material in terms of magnetic flux distribution
- Almost round leg shape with 96% fill-factor of the core leg circle
TriDry Transformer: compact II
Smaller footprint and lighter

Characteristics:
- Smaller footprint (approx. 25% less square footage)
- Length reduced
- Square footprint form factor allows large variety of bus coordination options

Matching characteristics: TriDry transformers are 20-30% lighter!
TriDry Transformer: premium features
New core construction leads to notable advantages

Reduced NLL & sound level

- TriDry transformers have B₀ NLL
- The unique features of the core result in noise level improvements of 5-10 dB compared to standard-grade steel.

Reduced inrush current

- ABB tests for inrush current with positive and negative remanence bias in the core. Tests on similar units indicate a strongly reduced inrush current for the TriDry transformer.

![Inrush comparison chart]

Y-axis: Multiple of primary current
X-axis: Initial current direction

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May 20, 2013 | Slide 22
TriDry Transformer
Summary

- **Compact**: different and more compact footprint, less weight and length
- **Efficient**: 20-30% lower no-load loss at same material usage or up to 20-30% lighter for certain efficiencies
- **Safe**: all the advantages of dry-type insulation in a robust, symmetrical package. Additionally lower magnetics fields.
- **Short delivery times**: thanks to standardization; most of the common ratings in stock
Dry Transformers
VSD and converters applications
VSD and converters applications
Segments

- Cement, mining and minerals
- Power generation
- Petrochemical
- Metals
- Pulp and paper
- Water plants
- Marine
- Oil and gas
- And many more…
Special design for VSD transformers I

- **Due to the flow of harmonic currents** in both Low voltage and high voltage windings, there are extra losses and extra heating, thus the transformer must be over rated according to a higher equivalent power.
- **Due to the flow of harmonic currents** through the network and transformer impedance, there is a voltage distortion (voltage harmonics) on the transformer magnetic core, which could be saturated. To avoid core saturation, the magnetic core must be over sized.
Additionally, in case of three or more winding transformers, the low voltage winding placed at top position must be over rated because of its worse cooling conditions (hot cooling air coming from the bottom low voltage winding).
In order to avoid capacitate coupling between high voltage and low voltage, as well as to protect the power electronics devices on the low voltage side, it is recommended to place an electrostatic shield between high voltage and low voltage windings.

In some cases (i.e. ACS1000), due to floating systems or high $du/dt$, higher insulation levels on low voltage windings are needed.
Antofagasta Minerals Esperanza Project

- Location: Chile
- 2 x 2400 kVA, 3300 / 1903 – 1903 V
- 3 x 1000 kVA, 3300 / 1903 – 1903 V
- 1 x 832 kVA, 3300 / 1903 – 1903 V
- 4 x 2840 kVA, 3300 / 1903 – 1903 V
- 4 x 567 kVA, 3300 / 1903 – 1903 V
- 2 x 400 kVA, 3300 / 1903 – 1903 V

- For ACS 1000 application
- Vector Group Dy11d0
- Temperature control device TMD – T4
- Sensors Pt100
- Metallic enclosure IP 34
- Electrostatic screen
- For outdoor application
### ThyssenKrupp Germany

<table>
<thead>
<tr>
<th>Units</th>
<th>kVA</th>
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<tr>
<td>2</td>
<td>6500</td>
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<tr>
<td>6</td>
<td>6250</td>
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<td>5100</td>
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<tr>
<td>1</td>
<td>3150</td>
</tr>
<tr>
<td>12</td>
<td>2500</td>
</tr>
<tr>
<td>2</td>
<td>2180</td>
</tr>
<tr>
<td>6</td>
<td>2000</td>
</tr>
<tr>
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<td>3</td>
<td>315</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
</tr>
</tbody>
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Dry-type transformers serving drives for customer satisfaction. Based on:

- integrated solution consisting of drive and transformer package.
- tailored transformer design for ACS800, ACS1000, 1000i, 2000, 5000, 6000, LCI
- deep understanding and know-how at ABB factories
72.5 kV dry-type transformer

Connections

- Insulated cable
- Non-insulated cable
- Wall bushings
Amorphous core transformers
Material characteristics

- Lack of crystal structure ➞ 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
72.5 kV dry-type transformer

Outdoors: a mechanically demanding design

- Special request:
  - Enclosure galvanized and painted
  - Roof (two sides)
  - Screws and nuts (stainless steel)
    - A) On-shore: Core clamping standard (painted)
    - B) Off-shore (and by the sea): Core clamping C4H
  - However big impact in size comparing to IP00
  - IP degree will depend on ambient conditions:

<table>
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<tr>
<th>IP23</th>
<th>Protected outdoor areas</th>
<th>a) AN b) ANAF</th>
<th>a) Natural convection b) Occasional usage of fans</th>
<th>Minor conductivity (caused by condensation)</th>
<th>Regular condensation</th>
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<td>unprotected outdoor areas</td>
<td>a) AN b) ANAF</td>
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<td>Minor conductivity (caused by condensation)</td>
<td>Regular condensation Rain</td>
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<tr>
<td>IPX4D</td>
<td>unprotected outdoor areas</td>
<td>a) AN b) ANAF</td>
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<td>Regular condensation Rain Snow Ice Fog</td>
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</table>
AMDT active part assembly process
Extensive ABB expertise in wound core DT technology
Special converter transformers
Traction application with factor coupling K>0.9 and LV foil winding

- Factor coupling K>0.9 LV foil winding:
  - There is high coupling factor
  - Impedance LV1 to LV2 less than 1%
  - Impedance HV→LV1 = HV→LV2 with -+1.5% variation according EN 50329 standard
  - Unbalanced current in LVs could be taken into account due to the low impedance between LV1→LV2
  - The lead bar are not coupling, take in a count for factor coupling calculation
  - The high resistance of Al help the unbalanced current
  - Due to the unbalanced current in LV are recommended for drivers in serial connection
  - Very low drop tension in LV1→LV2
The number of turns of low voltage windings must be modified in order to reach the voltage ratio between these two low voltage windings.

The impedance between low voltage windings must be matched by calculating and manufacturing carefully the windings dimensions.

The space factor is more critical because of the insulation gap between windings, and the larger size of the transformer.

In order to guarantee the correct losses and superior performance, the high voltage winding is split in two or more parallel circuits with two or more tap changers instead of one circuit.
Standard converter transformers
ACS 800 (high and low harmonic content)

Vacuum cast coil transformer characteristics:

- Two and three winding transformers
- 30° shift for 12-pulse operation (three-winding transformers)
- Maximum symmetry must be guaranteed between the secondary windings.
- Electrostatic screen between primary and secondary windings
- Transformers designed to withstand the harmonic content of the network
Standard converter transformers
ACS 1000 & ACS 1000i

- Secondary windings designed and tested with a superior insulation level.
- Maximum symmetry guaranteed between secondary windings
- Cross divisional cooperation within ABB in order to design the optimum transformers for the ACS1000 application
- Three-winding, dry type transformer
- Electrostatic screen between primary and secondary windings
- Five-winding, dry type transformers to operate with a 24 pulses generator integrated in ACS 1000 drive

Vacuum cast coil transformer characteristics:

- Example of common mode voltage wave form, measured on the secondary side phase to ground

24 pulses vacuum cast coil Transformer for an ACS1000i Drive
Standard converter transformers
ACS 5000 & ACS 6000

- 2 x four windings dry type transformers, to operate with a 36 pulse generator
- Electrostatic screen between primary and secondary windings
- Secondary windings designed and tested with a superior insulation level
- Maximum symmetry guaranteed between secondary windings

- 6-pulse: two windings dry type transformer. Casted secondary windings
- 12-pulse: 2 x two windings dry type transformers. Casted secondary windings
- 18-pulse: 3 x two windings serial connected dry type transformers. Casted secondary windings
- Additionally transformers for the ACS6000 ARU are designed and tested with a superior insulation level

Vacuum cast coil transformer characteristics:
Savings EcoDry99Plus

1,000 kVA

EcoDry99Plus

NLL 2.3 kW
LL 11 kW
13.3 kW total

NLL 1.5 kW
LL 6.8 kW
8.3 kW total

Savings
43,800 kWh/año
3,504 Eur/año
21.9 ton/ CO₂
Payback = 1.4 years

Electricity cost 0.06€ kWh.
8760h/year
working conditions at full load