



2017-07-11, DATA CENTER FORUM - SINGAPORE

ABB Dry-type Transformers

Dry transformers: providing valuable solutions to many electrical systems' challenges.

Michael Goggioli, CoE Dry Transformers for Data Centers

Agenda

ABB Group

Product Group Dry-type transformers



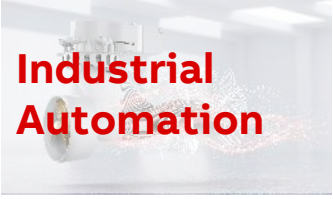

Challenges & solutions

- Inrush currents in transformers
- Vacuum circuit breakers and voltage surges
- High temperatures – overloads - lifetime
- Neutral creation
- High voltages

Q&A

Four market-leading entrepreneurial divisions

All businesses in #1 or 2 positions

	Partner of choice for...	Position	Revenues ²
	...electrification of all consumption points	#2 in electrification	\$9.9 bn
	...robotics and intelligent motion solutions	#1 in motion #2 in robotics	\$7.9 bn
	...industrial automation	#1 in process control	\$6.8 bn
	...a stronger, smarter and greener grid	#1 in T&D	\$11.0 bn

Power Grids division organization

Delivering differentiated customer value

Leveraging portfolio and expertise to maximize customer value

Power and automation products, systems & service solutions across the power value chain

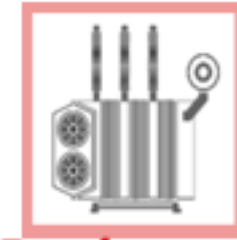
Global footprint ensures competitiveness and proximity to customers

Proven track record and unmatched worldwide installed base

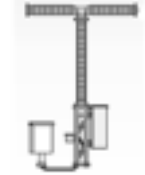
Lifecycle support services

Unparalleled domain expertise backed by skilled and experienced workforce

Offering solutions through four business units



Transformers



High Voltage



Grid Automation



Grid Integration

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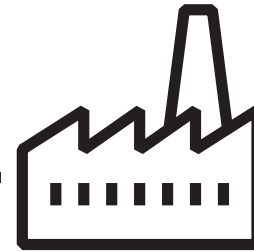
Q&A

ABB dry-type transformers

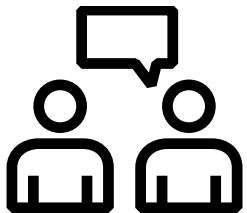
Facts and figures



Revenues: 600 MUSD /year
in more than 40 countries



Annual production capacity
around 30,000 MVA from 14 locations
More than 500,000 units and a field failure
rate of less than 1%



Around 1700 employees in 14 countries
6 technology centers worldwide

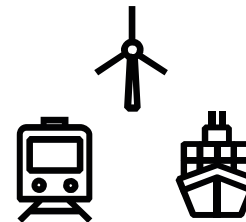


ABB has **the broadest portfolio** of dry-type
transformers available in the market

ABB dry-type transformers

Reliable solutions for all applications

Solutions for all applications



- Low voltage magnetics
- Transformers and reactors
 - Up to 1000 V and 10 MVA



- Sealed/submersible transformers
- Low maintenance, corrosion resistant
 - Up to 15 kV and 1.5 MVA



- Water cooled magnetics
- Transformers and reactors
 - Internal through conductor or external with heat exchanger



- MV magnetics
- Transformers and iron core reactors
 - Up to 36 kV and 20 MVA



- High efficiency transformers
- Amorphous core technology
 - Up to 36 kV, 100 kVA to 4 MVA



- MV or LV line voltage regulators
- Protects grid from network voltage variations
 - Up to 36 kV and 30 MVA



- HV transformers
- First dry-types for subtransmission
 - Up to 145 kV and 63 MVA



- Converter duty transformers
- Transformers for rectifiers, exciters and motor VSD's
 - Up to 36 kV, 10 MVA, and 48 pulse



- Special applications
- Custom magnetics for rectifier duty, railways and rolling stock, wind turbines, marine/offshore, etc.

ABB dry-type transformers

Customized technologies for special needs

Vacuum cast coil



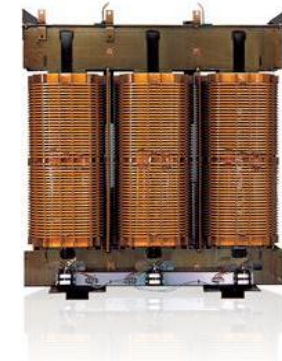
- Can reach highest voltage class for dry-type transformers (**145kV/550kV, BIL**)
- Suitable for corrosive, outdoor environments
- Smooth coils for easy cleaning

Resibloc



- Most robust winding technology
- Great for high current or high vibration applications
- Suitable for corrosive, outdoor environments (**-60°C**)

Open wound



- Highest insulation class (**220°C**)
- Most economical type of transformer
- Ideal for indoor environments
- Requires vacuuming of coils if dirty

Reliable, ecological, safe for people and ambient, maintenance-free

ABB dry-type transformers

Dry-type global producer with focus factories

Global footprint



Insulation technology

	VCC	Resibloc	VPI
USA	✓	✓	✓
Brazil	✓		✓
Spain	✓		
Germany	✓	✓	
Switzerland	✓		✓
Italy			✓
Bulgaria			✓
India	✓		
China	✓	✓	✓
S. Korea	✓		
Colombia – only assembly	✓		
Egypt - only assembly	✓		
S. Arabia - only assembly	✓		

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Q&A

ABB Dry-type Transformers

Challenge – Inrush current limitation

What is the inrush current?

When the transformer is first energized, a transient magnetizing (or exciting inrush) may flow in the windings, due to the core magnetizing process.

Many factors impact on the duration and magnitude of the current, among which:

- Size of the power system
- Type of core
- Flux density
- Prior history (residual flux)
-

This inrush current, which **appears as an internal fault to the differential relays**, may reach instantaneous peaks of 8 to 30 times the full load current.

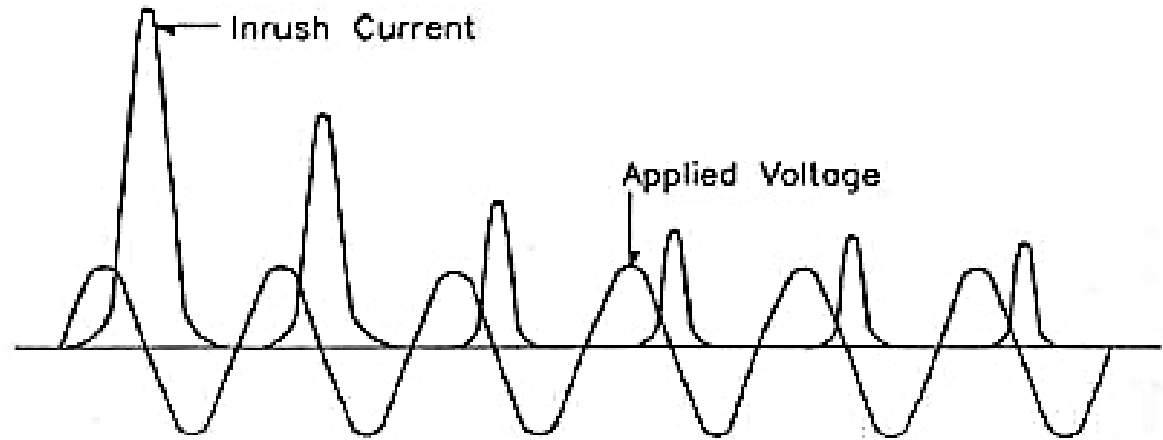


ABB Dry-type Transformers

Challenge – Inrush current limitation

Ways to limit it

Inrush current is mostly limited by:

- Increasing the reactance of the transformer primary winding (impractical)

Consequence: unwanted transformer impedance value

- Decreasing the core flux density and saturation point

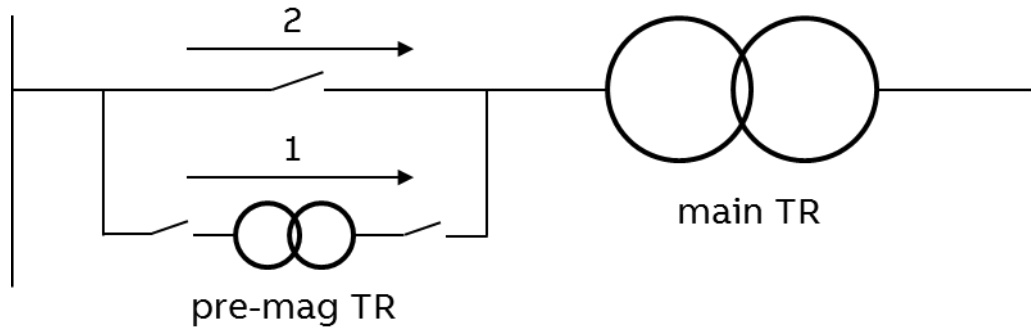
Consequence: higher transformer cost



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Solution – Pre-magnetization transformer

From MV side



Note:
The pre-mag transformer rating is approx. 0.5~1% rating of the main transformer

From LV side

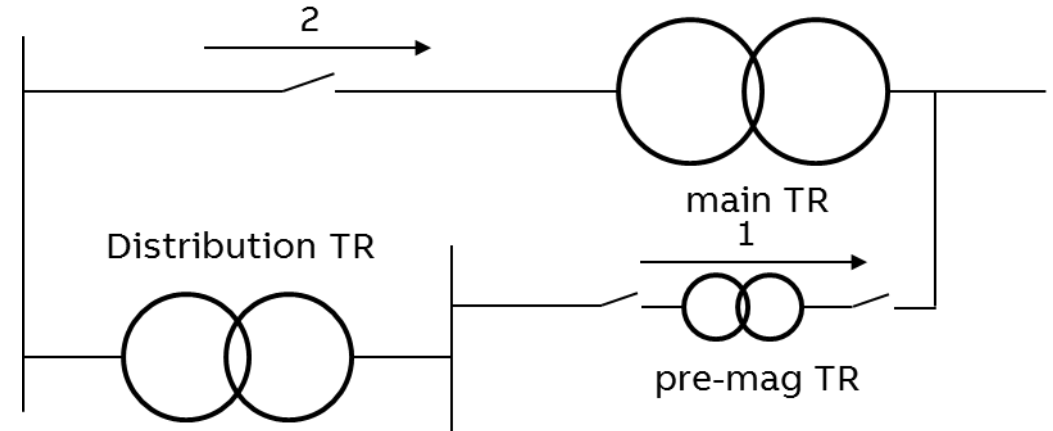


ABB Dry-type Transformers

Solution – Pre-magnetization transformer

Typical layout

Advantages

- Cancellation of inrush current
- Compact solution
- Relatively low cost
- Short cable runs

Simple, fast, reliable



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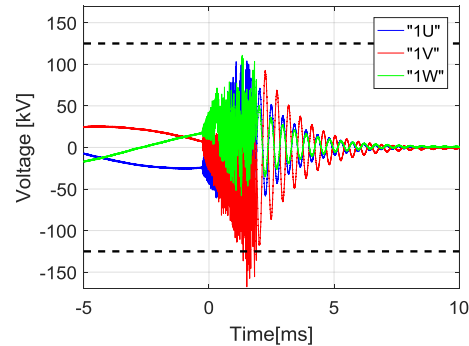
Q&A

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Challenge – Transformer operation with vacuum circuit breakers



Vacuum circuit breakers (VCB's) have incredible arc-quenching capabilities that bring increased safety and efficiency to electrical systems



However, VCB (and SF6) switching can produce fast transient overvoltages inside of transformer windings; some leading to failures

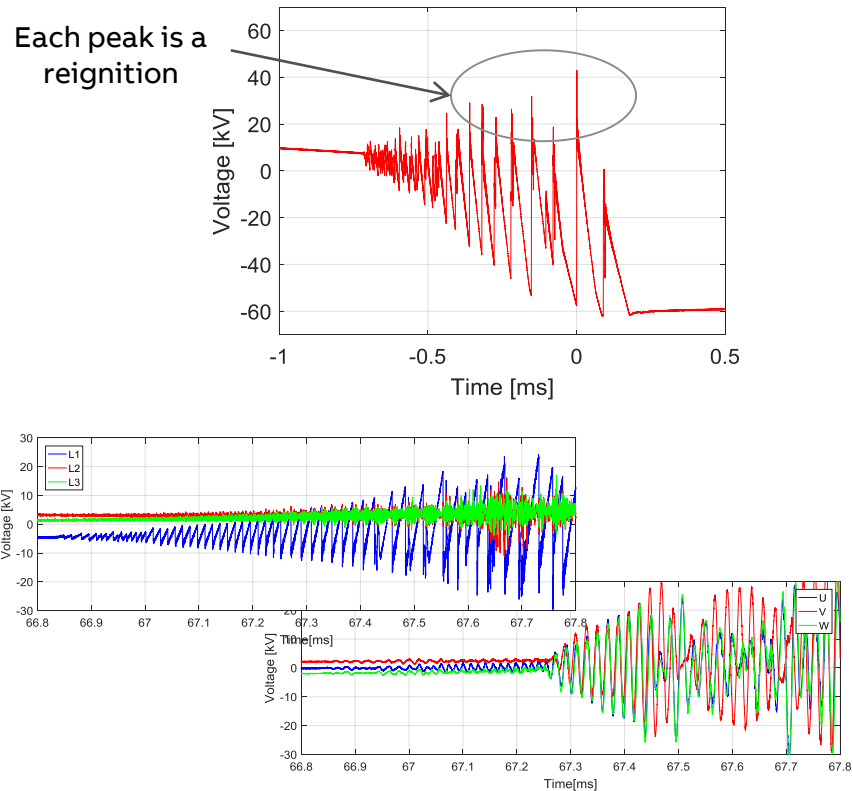


These failures result in system downtime and unrepairable equipment; both incredibly costly to network managers

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Investigation - What is actually happening; two types of voltage stress

Voltage at transformer terminals



Voltage spikes due to pre- or re-strikes in breaker

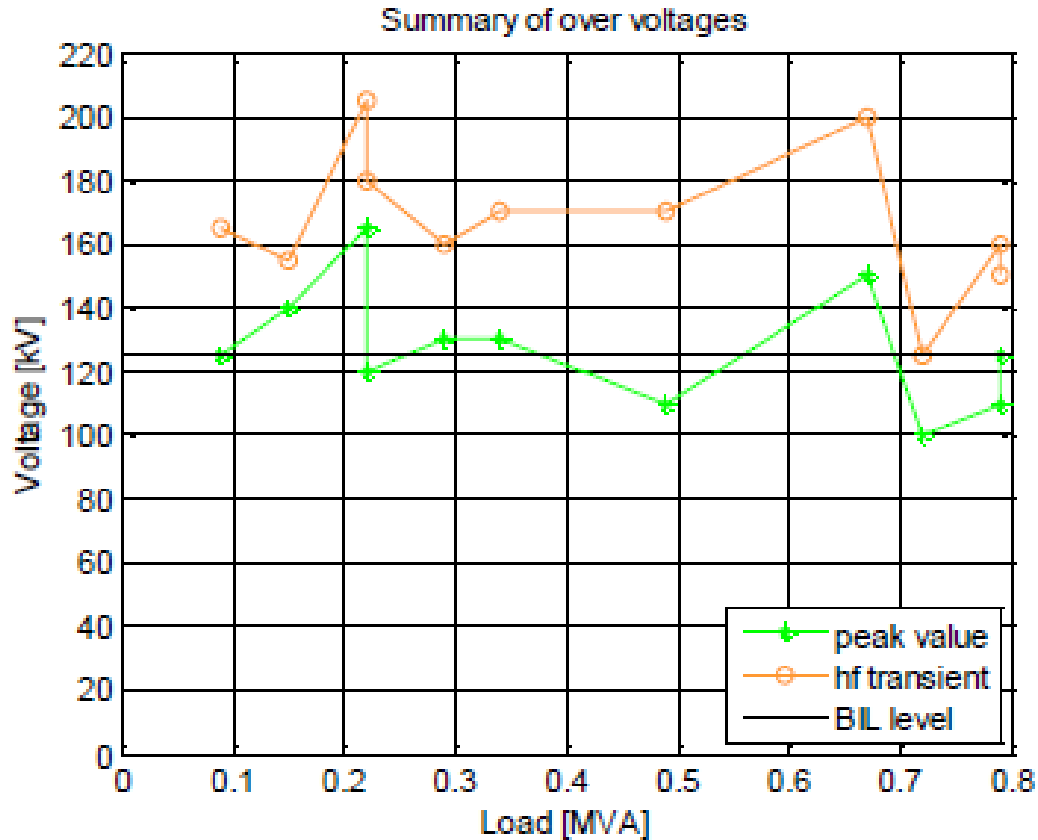
- Occurs when the voltage potential across the poles of the circuit breaker are still high enough to cause a spark across the terminals
- Chance to occur during every switching event with current

Voltage rise due to resonance amplification

- Occurs when sustained current (ex. short circuit) is interrupted and the wave frequency matches the natural frequency of the windings
- Depends greatly on system characteristics
- Least captured case during lab testing

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Investigation - peak voltage vs. current chopping level



Many variables make peak voltages unpredictable

Test: Full unit, disconnect with variable loading (graph)
– Result: Peak voltages are large and unpredictable

Conclusion:

– It is *impossible* to predict the max. peak voltage and, therefore, *impossible* to design a stand alone winding to resist fast switching for all scenarios, no matter the transformer technology

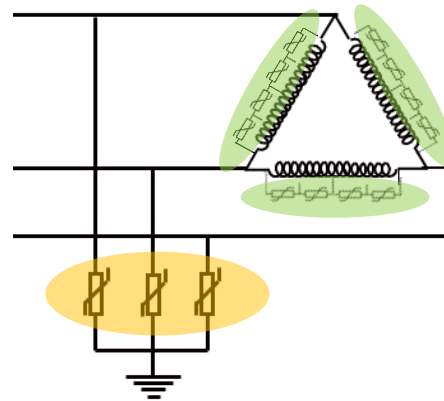
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Solution - Transient Voltage Resistant™ Transformer (TVRT)

ABB's solution to avoid TVs

The TVRT:

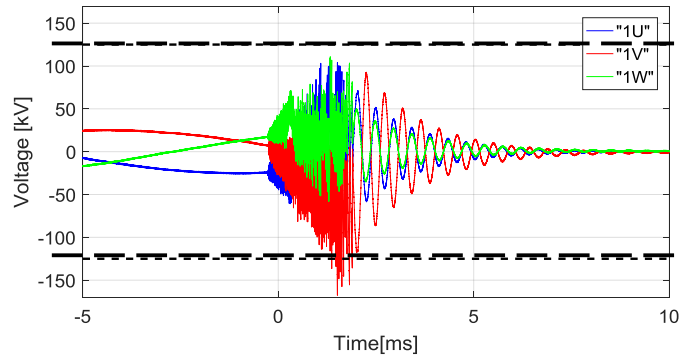
- **Varistors** are strategically integrated into the transformer windings to enhance the coil technology
- The varistors act as a pressure relief valve, preventing over-voltages inside the coil from growing beyond known levels
- With the peak voltage known, then the internal windings are designed to resist
- **This solution works in ALL system configurations because it prevents voltage rise**



Advanced solutions; winding varistors

Solution - Worst case switching scenario comparison

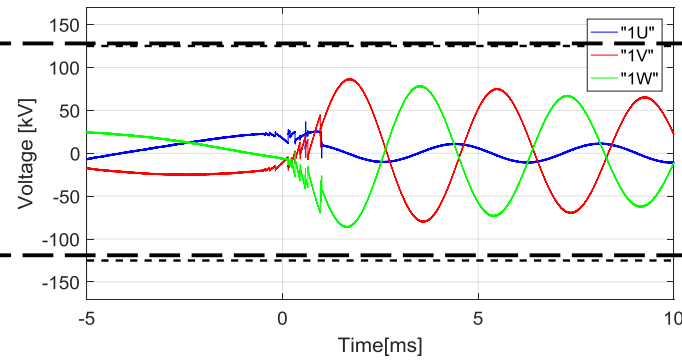
No protection



- Delta primary, VCC
- 168 kV peak voltages

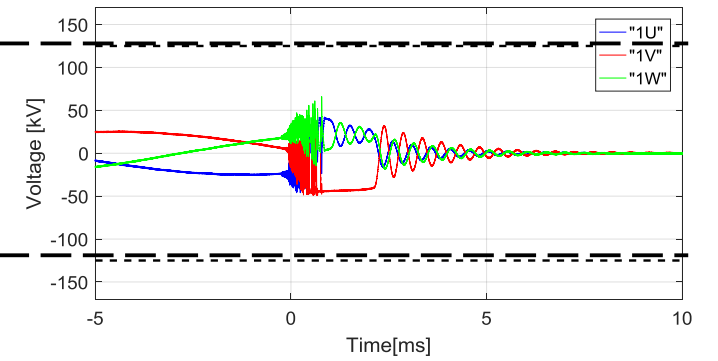
— — — — **BIL of test transformer**

RC snubber circuit



- Delta primary, VCC
- 250 Hz oscillation,
85 kV peak amplitude

Winding varistors



- Delta primary, VCC
- 40 – 45 kV (hf transients
up to \approx 65 kV)

Varistor arrangement shows clear reduction in peak voltages AND number of reignitions

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Product Group Dry-type transformers

Challenges & solutions

- Inrush currents in transformers
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- **High temperatures – overloads - lifetime**
- Neutral creation
- High voltages

Q&A

ABB Dry-type Transformers

Challenge - High temperatures – overloads - lifetime

Data Center distribution transformers

Design challenges

- **Harmonic currents** present in distribution lines can cause overheating and saturations difficult to quantify, that force to oversize the transformers.
- **Overloading** due to extreme operation conditions can also decrease a standard transformer lifetime if not correctly considered.
- **High ambient** temperatures in summer conditions can create unexpected trips in the distribution line and deteriorate the insulation.



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Solution – High Temperature Transformer (Hi-T Plus)

Hi-T Plus - High temperatures

- Insulation suitable for temperatures up to 180 °C and 220 °C as hot spot.
- Suitable for saline atmospheres.
- Vibration proof.
- Design tested up to 250 kV BIL.
- Optional design up to –40 °C.



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Solution – High Temperature Transformer (Hi-T Plus)

Transformer ageing prevention

Hi-T plus – High temperature insulation system

- Transformer insulation system is suitable for temperatures up to 180°C
- Suitable for saline atmospheres
- Vibration proof
- Design tested up to 550 kV BIL
- Designs available for operation at -40°C

Discuss it with our engineering team!

Transformers	Standard		HI-T Plus	
Resin characteristics				
- Insulation class	155°C		180°C	✓
- Average temperature rise	100 K		125 K	✓
Transf. characteristics				
- Full load temperature rise	100 K	✓	100 K	✓
- Admissible overload	0		25 K	✓
- Extra power	0		15%	✓
- Impact on lifetime	0		x8 approx *	✓

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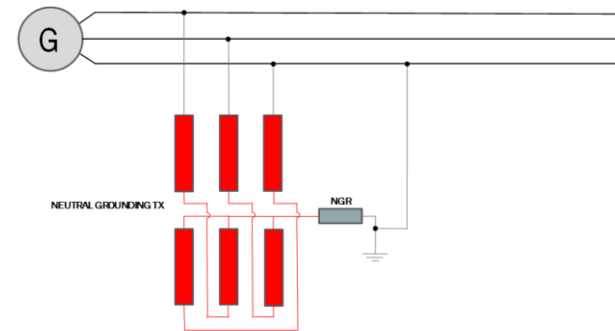
Generator neutral creation

Challenge

Generators supplying in delta configuration need an artificial neutral in order to allow **limitation of unbalanced currents** and of **fault currents**.

Grounding is generally achieved via a Neutral Grounding Resistor however the Ohmic value of the resistance and its insulation level may have heavy impact on its cost.

Solution



Creates an artificial neutral by using a zigzag or delta-star grounding transformer with a low voltage secondary winding
It can be connected to a suitably rated resistor of which the other terminal is earthed

Reduces the insulation level and Ohmic value of the NGR

Allows monitoring of the currents

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- **High voltages**

Q&A

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Challenge – Safe and ecological substation equipment

Requirements

- | | |
|--|---|
| – Safety for people | No flammable materials
No pressurized tank
Self-extinguishing transformer |
| – Safety for the environment | No oil as main insulation
No possibility of oil spillage
Low fire load |
| – Low amount of civil works and maintenance | No oil-containment systems
No fire-fighting system
No oil maintenance |



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Solution – High voltage substation transformer (Hi-Dry)

Design challenges

- Ratings up to **63 MVA**
- Voltages up to **145 kV**
(Impulse 550 kV IEC / 450 IEEE)
- 17 positions OLTC on Primary side
- Suitable for indoor or outdoor installation
- Cooling AN, ANAF, AFAF, AFWF
- Partial discharges < 10 pC



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Challenges & solutions

- Inrush currents in transformers → Pre-mag transformer
- Vacuum circuit breakers and voltage surges → Transient Voltage Resistant™ Transformer
- High temperatures – overloads – lifetime → Hi-T Plus transformer
- Neutral creation → Earthing transformer
- High voltages → Hi-Dry (145 kV) transformer

Q&A

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Reasons for choosing ABB

Why ABB dry-type transformers?

With the largest global production and installed base, we are your number one partner for worldwide initiatives

Solutions for any application

From offshore arctic oil platforms, to up-top wind turbine nacelles, to the world's tallest building, we have a custom solution to fit your need

Large portfolio of product

Abilities include a full line of LV magnetics, MV distribution and rectifier duty, and the first for sub-transmission, we are your one-stop-shop for dry-type transformers

Safety for people and property



Ecological and environmentally friendly



Easy connectivity to any system



Reliable, high quality, and low maintenance





ABB