

## Study Committee A2

Power transformers & reactors

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# Dry-type 145 kV transformers: safe indoor substations with improved environmental performance

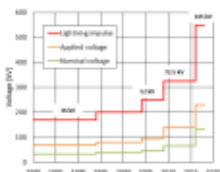
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## Motivation

Historically, dry-type transformers had been limited up to a voltage level of 36 kV

After the successful market adoption of the 72.5 kV level (e.g., AC 140 - LI 325 kV) in recent years, we decided to develop a solution for the next voltage level (e.g., 145 kV, AC 230 - LI 550 kV)

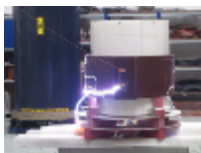


## Research and development process

The R&D was split into two steps: a series of Design of Experiments, and the manufacturing and testing of a whole 5 MVA transformer as demonstrator

### 1. Design of Experiments (DoE)

- Testing of real scale parts of the transformer, e.g., models where only a part of the insulation system was tested under AC and LI
- The models were used to test the following insulation clearances: between HV and LV windings, including the LV bars; between HV and magnetic core, including the clamps; between HV windings of adjacent phases; between terminals along the same HV winding



### 2. Manufacturing and testing of a 5 MVA demonstrator

- The determination of the insulation clearances of the demonstrator were based on the findings in the Design of Experiments
- A whole transformer allowed the testing of the LI with the real voltage distribution along the windings. It also was necessary to do the heat-run test and to measure the partial discharge (PD) level
- The 5 MVA demonstrator passed all the tests with minor changes, including a demanding partial discharge level <10 pC

Rated power	5 MVA
Nominal voltage	110,000 / 10,500 V
Off-circuit tap-changer	±8 x 2.25%
Insulation level	145 kV
Applied voltage	230 kV
Lightning impulse	550 kV
Connection group	YNyn0(d5)
HV winding technology	Foil disk



## Pilot substation

After its positive experience with dry-type 72.5 kV transformers in several hydro power plants, Duke Energy chose dry-type 145 kV for replacing an old unit at Jocassee Pumped Storage Facility



- The old transformer was a 3x1 MVA three-phase bank in an outdoor substation on the shore of the lake. Eliminating the risk of water contamination was the primary reason to change from oil-filled to dry-type
- A 3 MVA three-phase transformer replaced the bank, achieving a reduced footprint for the substation

Rated power	3 MVA (1 MVA unloaded tertiary)
Nominal voltage	100,000 / 600 / 0900 V
Off-circuit tap-changer	+3 -1 x 2.5%
Insulation level	145 / 72.5 kV, HV line / HV star
Applied voltage	230 / 140 kV, HV line / HV star
Lightning impulse	550 / 325 kV, HV line / HV star
Connection group	YNyn0(d5)
HV winding technology	Foil disk

## Dry-type 145 kV transformer

It was agreed to manufacture and initially test just one phase to validate the design, so the full transformer would then be manufactured later with almost full certainty

- The phase passed the tests, so the full transformer was manufactured without changes in the design
- The full transformer was tested in the presence of the customer. It passed all tests successfully, remarking a PD level <10 pC, AC 230 and LI 550 kV



The old outdoor substation was turned into an indoor one. Commissioning and energization were carried out in 2020



## Conclusions

- Dry-type technology is already proven for 145 kV level
- It allows to provide power to downtown areas and be used in hydro or other renewables
- Simple indoor and outdoor installation. The safest solution for people, property and environment

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