# DRY-TYPE TRANSFORMERS FOR SUBTRANSMISSION

Mariano BERROGAÍN
ABB s.a. - Spain
mariano.berrogain@es.abb.com

Martin CARLEN
ABB Ltd. – Switzerland
martin.carlen@ch.abb.com

## *ABSTRACT*

*The development of a dry-type transformer for the 72.5kV voltage class was already presented at CIRED 2011 [1]. Since then, large interest has been shown by many utilities as well as industries, because of the benefits inherent to the dry technology, meaning superior safety for people, property and the environment. These features make these transformers particularly suitable for installations in the following applications: urban substations, substations located close to or in public or private buildings or in caverns, power generation plants, water protection areas and for industrial applications, especially in the chemicals, oil and gas segments.*
*The availability of a dry-type on-load tap changer has supported the introduction of the HiDry$^{72}$ transformer product in the market. First installations, routine and type tested, have taken place and are presented in the paper. The transformers are used in different indoor and outdoor applications.*

## INTRODUCTION

The dry-type transformer for the 72.5 kV subtransmission voltage level offers all general features of dry-type transformers. The major benefit is the lack of flammable liquids, which are typically used in oil-filled power transformers. The dry-type transformer is non-explosive and self-extinguishing. In case of an external fire its combustible mass is much smaller and much less smoke is created. The transformer is therefore ideally suited for indoor and underground installations.

At subtransmission voltages, substations are mostly outdoor installations. In case of indoor installations, GIS switchgear equipment is used and the transformers are often placed outdoors, making such installations impractical or even not possible. If an indoor installation of an oil-filled transformer is required, adherence to fire protection regulations can be very costly

The dry-type transformer is changing these limitations and will allow safe and compact indoor and underground substations in the future. This increases the possibilities and flexibility for substation design and reduces insurance costs and other liabilities. Thanks to having air as major the insulation medium, the technology is highly reliable and is not exposed to the risk of gas leakage related to the use of special insulation gases.

Since dry-type transformers for the 72.5 kV voltage level are new, some aspects need special attention. First, in contrast to distribution applications, the transformer generally needs to be equipped with an on-load tap changer (OLTC). The availability of an OLTC is therefore a key requirement. In order to not negatively affect the overall safety of the installation it also needs to be of dry-type technology.

Second, as mentioned above, present substations are mainly outdoor substations. The use of dry-type technology can also offer benefits in such cases, e.g. no risk for water contamination by leaking oil, or reduced fire risk in forest or industrial areas, at buildings or at heavily populated locations. For outdoor installation of dry-type transformers appropriate enclosures are required, with an IP degree reflecting the specific conditions of the location.

Third, transformer retrofit in existing substations requires the dry-type transformer to have a similar footprint as the previously installed oil-filled transformer, in order to fit into the available space,. The experience so far has shown that this is often the case. Forth, extension or retrofit of existing substations may require transformers to be installed in parallel. Thanks to high design flexibility, it is possible to match the characteristic of existing oil-filled units in many cases.

**Fig. 1:** Dry-type subtransmission transformer: 66 kV / 10 MVA

When evaluating the case for using of dry-type transformers it is important to consider all aspects and costs related to the whole system installation and not just the costs of the transformer. Considerable savings can be achieved if all installation and operation related costs are considered, including civil works, infrastructure costs and costs of energy losses and maintenance.

## 72.5 KV DRY-TYPE TRANSFORMER

Dry-type transformers for the 72.5kV voltage class are available with the following characteristics:

| | |
|---|---|
| Rated power | up to 63 MVA |
| Primary voltage | up to 72.5 kV |
| Lightning impulse voltage | 325 kV for IEC<br>350 kV for ANSI/IEEE<br>190 kV for GOST |
| Short duration AC withstand voltage | 140 kV for IEC<br>140 kV for ANSI/IEEE<br>85 kV for GOST |
| Secondary voltage | up to 36 kV |
| Connection group | Y or D |
| Partial discharge | <10pC |
| Insulation class | F (155°C) or H (180°C) |
| Environmental class | E2 |
| Climatic class | C2 |
| Fire class | F1 |
| Cooling | AN, ANAF, AFAF, AFWF |
| Tappings | 17 positions (± 8 x 1.25%) |
| Enclosure | IP21 (indoor) to IP54 or IPX4D (outdoor) |

**Table 1:** Characteristics of 72.5 kV dry-type transformers

72.5 kV dry-type transformers are available with vacuum cast coil (VCC) or RESIBLOC® coil technology. The VCC technology uses foil disk windings together with a well proven and high quality epoxy resin and silica filler casting technology. The ABB unique RESIBLOC® transformers are cast resin transformers reinforced by glass fiber filament. Due to this reinforcement they offer superior mechanical strength, making them most suitable in the event of extraordinary loading cycles or short-circuit current. RESIBLOC® transformers offer excellent performance in very cold climates and can be operated at temperatures as low as -60°C.

In either case, the design and production of the transformer is completed with special care and attention. Main design differentiators are related to the strengthened and high quality insulation, special HV terminals, control of electric fields, use of rounded components and shields, appropriate dielectric distances and special supports to increase creepage distance and avoid leakage currents. The windings can be made either with aluminum or copper conductor.

**Fig. 2:** Dry-type on-load tap changer for the 72.5 kV voltage level, consisting of a switching unit for each phase and a common drive

No IEC or ANSI/IEEE standard exists currently for dry-type transformers with voltage class of 72.5kV. Therefore the respective standards for dry-type and oil-immersed transformers are applied, whenever relevant.

## ON-LOAD TAP CHANGER

The OLTC used in HiDry$^{72}$ is based on dry-type, oil-free technology, using vacuum interrupters for switching. A linear configuration is chosen. This configuration has been used for dry-type OLTCs at lower voltages for many years and is well proven. Accordingly, the HV windings are designed for such a linear type of OLTC.

The OLTC consists of a separate unit for each phase, mounted in front of the respective transformer coil. The phases are commonly operated from a single drive via a common shaft (Fig. 2).

The actual solution offers 17 positions, and a tapping range of ±10%, with a maximum voltage step of 900V. The maximum current is 500A. The ratings of the OLTC will be extended in future. The number of electrical operations are 100'000, but improvements are ongoing and the number will further increase. Very little maintenance is required with a dry-type OLTC. The actual product allows atmospheres of pollution level II.

The connection between the taps of the dry-type transformer and the OLTC contacts is done using insulated cables. The insulation between individual cables and between cables and ground has to be properly dimensioned for withstanding the operational and lightening impulse voltage levels.

## HV CONNECTIONS

The high voltage connection to the transformer itself is very straightforward. It can be achieved with insulated or non-insulated cables, or directly from the busbars. The type of connection depends on the specific installation. If a cable is coming to the transformer, the cable termination can directly be mounted on the transformer coil. If an overhead line is coming to a building a wall bushing is needed for entering the building (Fig. 3).

The transformer itself does not have any bushing. It will

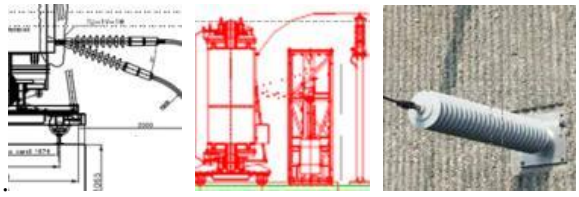

**Fig. 3:** Different types of HV connections: cable with cable termination (left), connection with non-insulated cable (middle), wall bushing (right)

therefore not be affected by problems related to bushings which are often experienced with oil-filled transformers.

A wall bushing is also needed in case an enclosure wall needs to be passed and a cable connection is not possible. For many indoor installations an enclosure will not be necessary and fencing of the transformer for security reasons is sufficient.

## ON-GOING PROJECTS AND INSTALLATIONS

In the following examples we present a selection of customer projects showing different installation and application possibilities.

### Grid Operator: Red Electrica de España (Spain)

A 1'800 kVA, 66/0.44 kV VCC transformer was delivered in 2012 for outdoor installation on the Canary Islands, Spain. An IPX4D enclosure is used (Fig. 4), withstanding the tough and corrosive maritime conditions on the island, close to the sea. Based on customer requirements, wall bushings are used for the connection of the high voltage. This allows delivery of the transformer fully assembled with the enclosure and easy and quick connection to the high voltage, without need for dis- and re-assembly of the enclosure.

The transformer installation is in connection with a Smart-Grid installation, using a flywheel for energy storage and supporting voltage and frequency stability in the grid.

**Fig. 4:** HiDry[72] transformer mounted in outdoor enclosure

Although the above installation is a fixed one, it can readily been seen that the ease of transportation, erection and connection, together with the absence of oil, makes such a transformer installation the perfect choice for moveable substations.

**Fig. 5:** 12 MVA, 66kV HiDry[72] transformer during assembly

### Industry: ABB Córdoba (Spain)

ABB operates a well-known factory for shell-type oil-immersed power transformers in Cordoba, Spain. In 2011 an upgrade of the entire electrical installation was pronounced, including substations and transformers. Key components of the Cordoba project are two HiDry[72] VCC transformers (Fig. 5), of ratings 12 MVA, 66/20 kV, and equipped with a dry-type on-load tap changer. The OLTC provides 17 positions and voltage steps of 1.25%. The installation is indoor and without enclosure. The two transformers were delivered at the end of 2012.

### Utility (Brazil)

Another installation is in Salvador de Bahía in Brazil, one of the cities hosting the 2014 FIFA Soccer World Cup. For this purpose the Fonte Nova Stadium was demolished after 60 years is being replaced by a new stadium (Fig. 6).

**Fig. 6:** Fonte Nova soccer stadium, Brazil, equipped with 69kV dry-type transformers

The building includes a substation (Fig. 7) with two VCC transformers, rated 25 MVA, 69 kV primary voltage, and adjustable for two levels of secondary voltage: 11.95 kV or 13.8 kV. They are provided with OLTC, offering +4/-12 x 1.25%. The indoor installation is without enclosure.

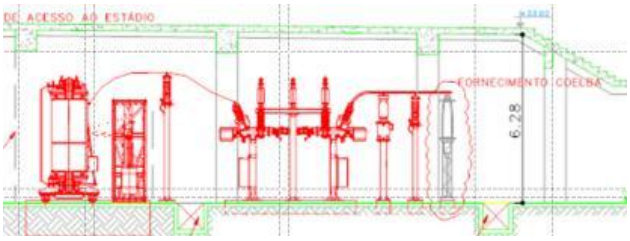


**Fig. 7:** Layout of substation in Fonte Nova stadium, located below main access to the stadium

The transformers supply the power to the stadium during the games, as well as to the surrounding city area. The transformers were delivered end of 2012.

This is a typical example where the safety features of dry-type transformers allow a safe compact installation, close to the load, in facilities where thousands of people are present.. The end user, which belongs to the Coelba –Neoenergía Group**,** part of Iberdrola**,** was particularly impressed attracted by the dry-type solution.

**Fig. 8:** Final assembly of 25 MVA HiDry[72]transformer and OLTC

## Utility: Ulricehamns Energi (Sweden)

A local utility in Sweden, Ulricehamns Energi, is installing a 16 MVA, 45/11kV HiDry transformer. 72.5 kV voltage class is required. The transformer uses RESIBLOC coils, especially suitable for the low temperature conditions in Sweden. It is equipped with an OLTC with voltage steps of +/-7x1.67%. The installation is an outdoor installation.

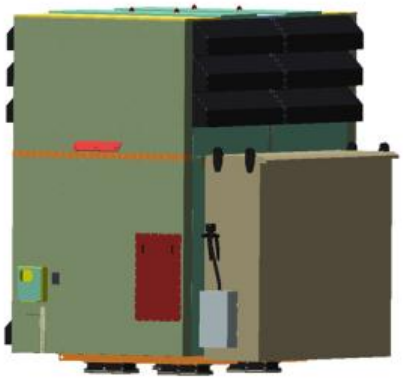

**Fig. 8:** Transformer with outdoor enclosure and attached OLTC

The transformer has a IPX4D enclosure, i.e. is protected from splashing water and against contact with wire-like devices. Ulricehamns Energi decided for an oil-free transformer due to installation in an environmentally sensitive area. The transformer is delivered finally installed in the enclosure. The OLTC is mounted in a separate enclosure, where it is easily interconnected with the transformer enclosure. This modular concept allows easy transportation and fast installation of the separate components.

**Fig. 9:** Views of the 16MVA transformer inside the enclosure

## Industry: Sandvik (Sweden)

Another example is also from Sweden, at Sandvik Materials Technology. A 15 MVA, 42,5/3,5kV transformer of voltage class 72.5 kV and using RESIBLOC coils is installed for distribution purposes. The installation is outdoor with an IP23 enclosure.

By replacing an older oil transformer with a dry-type one, the customer reduces the fire risk on his plant and also reduces maintenance costs. The transformer fits into the bay of the existing transformer. The transformer is being delivered in early 2013.

**Fig. 10:** Location of the oil transformer being replaced by a dry-type one

## DISCUSSION AND CONCLUSION

The introduction of dry-type transformers for subtransmission applications is a major step in providing equipment with increased safety for people, property and the environment. It allows to use new concepts to be used for substation installations in buildings or underground applications.

At the subtransmission voltage level, in most cases an OLTC is needed. As the reference cases show, OLTCs are also available in a dry-type version.

Besides the typical indoor applications, solutions for outdoor installations are easily achieved using enclosures of appropriate IP degree. Transportation, erection and installation of transformers is easy and fast and the required footprint is similar to that of oil-filled transformers of comparable ratings.

The opportunity to use a dry-type transformer in combination with existing oil-filled ones, operating them in parallel, allows to gradually change existing substations to the safe dry-type technology when the end of life of existing transformers is reached.

## REFERENCES

[1] J. Tepper, R. Murillo, C. Roy, J. Smajic, M. Erichsen, M. Berrogaín, 2011, "Dry-type transformers for the 72.5kV voltage class", Paper 0984, CIRED, June 6-9 2011, Frankfurt