Some operators request the bushings to withstand the effects of an internal arc for 0.5 seconds following a failure resulting in maximum short circuit current of the network

Internal arc testing of transformer bushings

ABSTRACT

This article discusses a special test on transformer bushings which has been introduced in the technical specifications of the Italian Transmission Operator. This test is used to increase the safety in case of an internal electric arc fault in a bushing, which might explode posing threat to human life and the surrounding equipment.

KEYWORDS

internal arc, withstand, short circuit, turret, bushing

1. Introduction

Safety is a very important factor to be taken into consideration in every area of life. In high voltage industry, where failure of electrical equipment may cause fatal accidents leading to catastrophic consequences and possible loss of life, safety aspects need to be considered from the inception of each product development.

High voltage (HV) and ultra-high voltage (UHV) plants and components play an important role in health and safety issues and the associated environmental aspects. Bushings, as components of HV and UHV systems, have been given a lot of attention in this regard and special tests have been introduced by utilities to prove their performance is safe even in drastic conditions.

All technologies that are applied in the bushing industry today have a very high level of operational reliability based on their long history and manufacturing experiences. While the traditional OIP (Oil-impregnated Paper) insulation technology is over 80 years old, the RIP (Resin-impregnated Paper) technology is more recent, but it has already

reached over 25 years of service. Over the time, both technologies have been refined and adjusted in all aspects, and consequently, they are very reliable today. However, the progress in technology allows us to take further steps for improvement in other areas, including health and safety.

Explosion resistant transformer bushings are equipped with composite insulator and able to withstand the internal arc-fault test

2. Test requirements

Recently, the Italian Transmission Operator, known worldwide as one of the leading companies in technical expertise, has taken a step in this direction, requesting to have the bushings which are able to withstand the effects of an internal arc following a failure that involves the rated short circuit current of the network.

This test is typical for other HV components, such as current transformers where the effects of an explosion due to an internal arc are really disastrous, acting as a bomb. For these components, this test has been performed for a long time and is well established by International Standards; however, it is new for bushings. A transformer bushing, even when equipped with a composite insulator which drastically reduces the effects of an internal failure, could blow out like a rocket, propelling the material or the insulator itself into the air. So, the request was made to use the composite insula-

Figure 1. Test turret

Table 1. Maximum short circuit currents that bushings have to withstand for 0.5 s depending on the voltage class

Voltage class	Short circuit current	Time
420 kV	63 kA	500 ms
245 kV	50 kA	500 ms
170 kV	40 kA	500 ms
145 kV	40 kA	500 ms

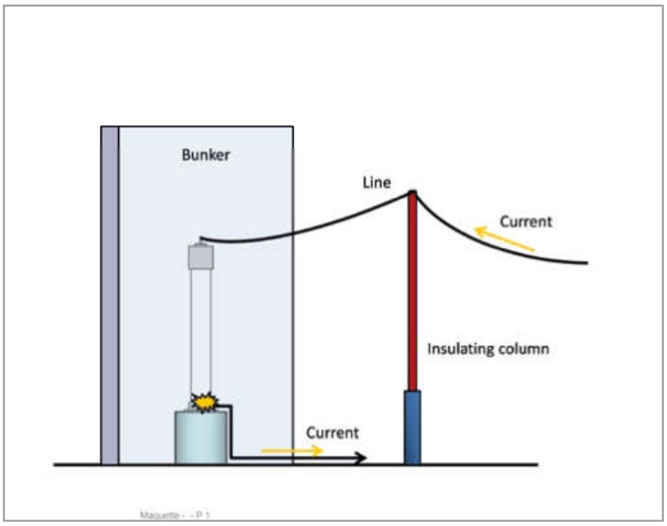

Figure 2. Circuit arrangement

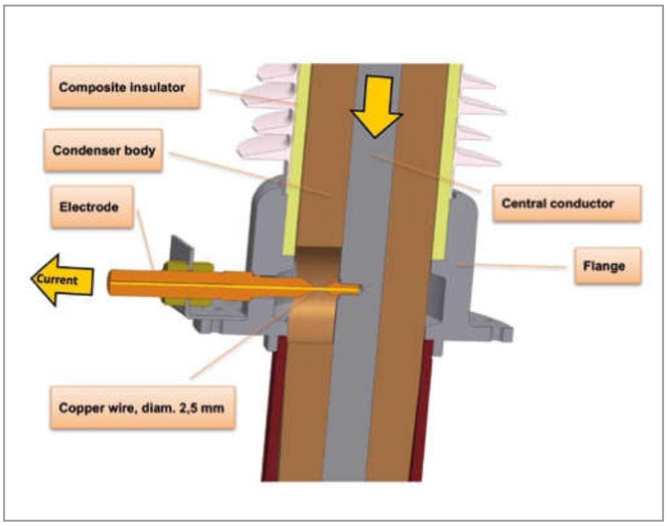

Figure 3. Bushing arrangement

During the test, the bushings are mounted and connected to simulate the service condition; the internal arc is generated with a thin copper wire which vaporizes after an initial current flow

Figure 4. External electrode

tors and perform an induced internal arc-fault test in order to raise the safety level of bushings against any kind of explosion.

A transformer bushing, depending on its voltage class, must be able to withstand the maximum network short circuit current for 0.5 s, as outlined in Table 1. The energy developed during this test is very high and the bushing design which satisfies the test criteria is considered to be intrinsically safe.

3. Test description

Two 420 kV transformer bushings, one with OIP and the other with RIP technology, were tested.

For the test, the bushing was mounted on a steel turret simulating the service condition on the transformer, Fig. 1. Externally, the connections were arranged in accordance with the service geometries, with the same flexible conductors and the same support insulator positioned at the same distance as in the substation. The aim was to reproduce exactly the mechanical stresses which occur during the service short circuit, Fig. 2.

The arc was generated inside the bushing with a special spark gap equipped with an arc igniting copper wire of a 2.5 mm diameter, Figs. 3, 4 and 5. The external electrode, Figs. 4 and 5, was connected to the external circuit, while the internal electrode was connected with the bushing central conductor; these two conical-shaped electrodes were electrically

Figure 5. Spark gap electrode

Figure 6. Test arrangement

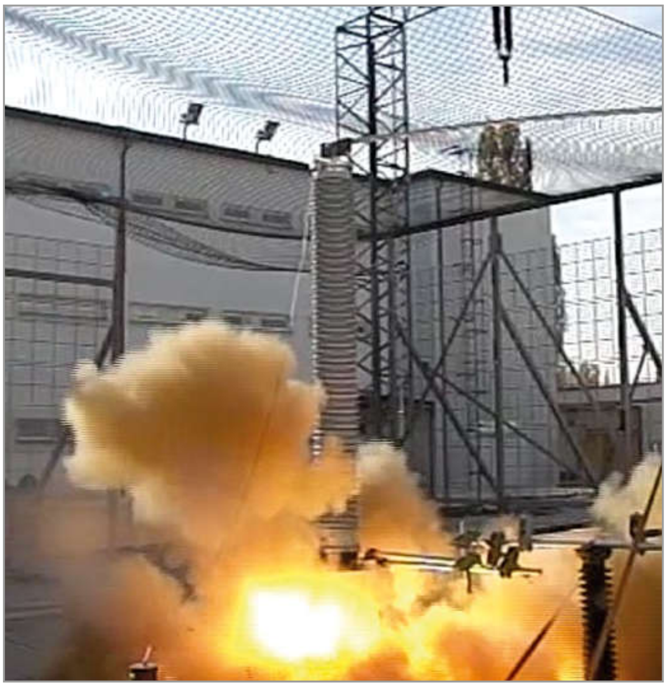

Figure 7. Internal arc pictures

connected by means of a copper wire, which acted as a fuse allowing the initial current passage and then immediately vaporizing, leaving the arc between the two electrodes.

Two 420 kV transformer bushings (OIP and RIP) successfully passed the test, without any explosion, big external damage or material being projected outwards

The whole arrangement was placed in a protected area, a sort of a bunker made of concrete reinforced walls, Fig. 6, to protect the surrounding equipment in case of explosion and consequent test failure.

The OIP bushing was subjected to a fault current of 63.5 kArms for 0.5 s, with a peak value of 148 kApk, while the RIP bushing was subjected to a fault current of 63 kArms for 0.5 s, with a peak value of 153 kApk, Fig. 7.

This current generated an electric arc in the bushing for a half a second, which developed a huge energy of about 13 MJ. For illustration, this energy is equivalent to that of a mass of 1000 kg launched at a speed of 580 km/h.

Both bushings have successfully passed the test, without any explosion, material being projected, or big external damage, Figs. 8 and 9, thus meeting the safety requirement of the new technical specification which states that no parts can be projected outside a circular area of three metres in radius around the bushing.

Figure 8. RIP bushing after the test

4. Conclusion

To increase the external safety around bushings, the Italian Transmission Operator introduced an internal arc test as a new technical requirement. According to this requirement, the maximum short circuit current of the HV network depending on the voltage class must be generated inside the bushing for half a second, and as a consequence, no explosions projecting solid material outside the bushing may occur. In order to meet this requirement, bushing design has been improved and the test has been performed on two 420 kV bushings in OIP and RIP insulation technology, both equipped with composite insulators.

Both bushings passed the test, demonstrating that even mature technologies like those of OIP and RIP bushings can be further improved to meet today's stringent safety requirements.

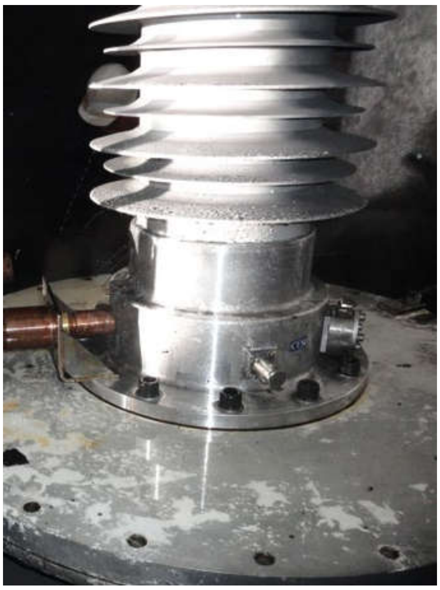

Figure 9. OIP bushing after the test

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