* Corona Processing of Insulating Oil

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Abstract

It is well known that sustained corona discharge in insulating oil lowers its dielectric strength and simultaneously reduces its corona resistance. Therefore, for operating stresses in the corona regime, activity typically increases with time and, if allowed to continue, eventually leads to breakdown of the oil and failure of the component or system. It is, therefore, common practice to periodically replace oil in devices such as large power transformers and switch gear before breakdown occurs. Sealed components such as capacitors are typically replaced.

Recent experiments have demonstrated that the dielectric properties of corona weakened oil can not only be restored, but actually improved by a simple regeneration process¹. These experiments were carried out on high voltage pulse transformer windings which were operated at high rep rates until partial discharges formed. Reprocessing the oil after each operating cycle resulted in successively longer operational periods before partial discharges appeared. In a separate experiment, a process was developed to precondition transformer oil to raise its corona inception voltage before using it to insulate a high voltage component, thus giving it a longer initial service life for a given operating stress or permitting higher stress operation for limited operating times.

Introduction

Corona processing of insulating oils is a complex process of partial ionization and recombination during which gases are formed^{2,3} and absorbed by the oil. As the volume of absorbed gases increases, the corona inception voltage (CIV) and dielectric strength characteristically decrease. This reduction of dielectric properties will continue and actually accelerate with continued operation until breakdown occurs. The process of corona-induced dielectric property change occurs in practically all oil-insulated high voltage equipment and represents the "wear-out" mechanism in capacitors and other sealed components where useful life follows well known stress-time relationships. Such sealed components are typically replaced when the end-of-life is near or failure occurs. With large power transformers, oil is usually replaced when the dielectric strength and CIV drop below certain limits. However, long-term experience with high voltage pulsed power systems and recent experimental evidence show that oil-insulated components that have undergone serious dielectric property degradation may be restored to serviceable condition and possibly improved in terms of corona resistance and time-to-failure.

This effect was first observed in megavolt pulse transformers which, when operated in a repetitive pulse mode at stress levels of near 150 kV/cm, would often experience minor internal breakdowns when the total shot count was about 10^7 . These transformers were fixed by evacuation of the

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oil in the windings during which large volumes of absorbed gas were removed. Evacuation was considered complete when the gas evolution ceased and the oil was "quiet" under vacuum. This general process was applied with equal success to transformers having different insulating oils such as transformer oil, castor oil, MIPB, and a polybutene-alkylbenzene mixture.

In subsequent operation, there never was an occasion when breakdown occurred again in the same transformer even with operating periods far exceeding the original. These observations led to the present series of experiments which clearly showed that the dielectric properties of insulating oils actually improved with successive cycles of stressing and vacuum regeneration.

Discussion

Two types of tests were conducted to study corona effects in oil. The first was a transformer winding pulsed to high voltage to measure the number of shots required to induce visible partial discharges. The other test involved generating partial discharges in a bulk oil volume to determine whether oil could be preconditioned. A 200 kV pulse generator with attached test tank was used for both sets of tests. (Fig. 1)

Fig. 1 Pulse Generator with Tank and Test Winding

The transformer winding was a spiral strip type with mylar/paper insulation. For testing, it was placed in a transparent container and vacuum impregnated with transformer oil. The assembly was then placed in the pulser oil tank such that the winding could be observed during the test. The center of the winding was pulsed to 200 kV with the external primary turn and grading rings held at ground. Fig. 2 is a typical voltage pulse record.

Fig. 2 Voltage Pulse 100 kV/div; 50 ns/div

Testing consisted of a series of runs at a pulse repetition rate of 25 Hz to observe the onset of partial discharges. Partial discharges typically originated around the external grading rings and were initially visible as faint, intermittent streamers on the surface of the insulation around the rings. The pulse count when small streamers first became visible, was noted and recorded as the approximate number of shots for a given test run. Allowing the test to continue for 2,000 to 3,000 shots after partial discharges were first detected resulted in growth of the streamers until they became bright and filled the margins (Fig. 3).

Following each test run, the winding and cylinder were evacuated until visible gas evolution ceased. They were then replaced in the pulser tank for another test run. It was found that the number of shots required to produce visible streamers increased with each test run and evacuation

Fig. 3 Transformer Winding with Bright Margin Streamers

cycle which indicated that the oil became more corona resistant with each test cycle. The following table lists the test runs and the shots to the visible streamer state:

<u>TEST RUN</u>	<u>OIL CONDITION</u>	<u>APPROXIMATE SHOT COUNT</u>
1.	new, dry & clean	18,000
2.	evacuated, dry	38,000
3.	evacuated, dry	85,000
4.	evacuated, dry	290,000
5.	evacuated, dry	500,000 (No streamers) (Test terminated)

Another remarkable result observed was that after evacuation, the streamers on the insulation did not track in the carbonized markings from previous test runs. In every case, the streamers found new paths and made new marks. Quite naturally, this leads to the conclusion that the film and paper insulation surfaces might be undergoing some form of conditioning also.

The increased corona resistance shown by the oil in the winding test series raised the prospect of preconditioning oil with corona and partial discharges. An experiment, therefore, was conducted where high voltage pulses applied to a conical steel

brush produced large volumes of partial discharges in an oil volume between the brush and a ground plane (Fig. 4A). A vacuum over the oil container removed the gases as they were formed. Evidence of corona conditioning was visual only. With a beginning condition of dense bubbles from partial discharges in the brush-ground plate gap, the density of the bubble cloud was seen to clear somewhat as the test progressed (Fig. 4B). The visual clearing of the partial discharges after a period of pulsing was taken as a positive indication that the oil was undergoing a conditioning process. This conclusion is confirmed by the fact that when the voltage was raised slightly, the bubble cloud density increased significantly. When it was lowered, the cloud cleared almost completely.

Fig. 4A Dense partial Discharges

Fig. 4B Reduced Partial Discharges After Prolonged Operation.

Conclusions

It has been shown that the corona resistance of insulating oils can be increased by repetitive cycles of operation or pre-stressing with evacuation. This process can not only extend the life of conventional components, but also permit designing systems and components for higher stress operation. For components such as transformers and capacitors that are assumed to be near the end of life when internal corona activity increases significantly, in-situ reprocessing may restore them to like-new condition. This process has been demonstrated with high voltage pulse transformers but remains to be shown for capacitors. Nevertheless, corona processing of insulating oils presents many prospects for innovative applications.

The prospect of pre-stressing insulating oils before installation in high voltage equipment opens the possibility of producing new generations of high energy density, long life components. Without pre-stressed oil such components would not be possible unless a new generation of oil were developed; a remote and expensive prospect at best.

References

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