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Power Transformer Bushings – Inspection, Testing and Refurbishment.

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SUMMARY

Bushings are among the most critical components of a power transformer (PT). In the majority of transformers, line terminals are taken out from transformer tank through the bushings, which provide a very effective insulation between the energized line conductor and the earth (transformer tank body).

Thermal and electrical stresses and environmental conditions are putting high demand on bushings. Because of the high levels of electrical stress in bushings, failures in oil impregnated paper (OIP) bushings with porcelain insulators tend to result in sudden and catastrophic failure of an explosive nature.

CIGRE Working Group (A2.37) determined that for utilities operating in several European countries, bushings were typically responsible for approximately 17% of all major HV (above 100 kV) transformer failures. Further, almost 50% of all serious transformer fires are initiated by the failure of OIP bushings and therefore, accurately classified as the single leading cause of transformer fires.

To maintain a world-class power transmission company, Hydro One uses a proactive strategy to maintain transformers through regular inspection, repair, refurbishment and replacement programs. The goal is to service existing assets before a costly failure and to have an inventory of spares available to reduce downtimes for transformer outages.

This paper presents a review on the bushing inspection techniques, condition assessment, testing, repair and refurbishment.

KEYWORDS

Power transformer bushings, refurbishment, overhaul.

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INTRODUCTION

Hydro One is Ontario's largest electrical service provider with over 240 transformer stations and over 1100 distribution stations built over the last 110 years. Many transformers, ranging from 15 kV to 500 kV, are still in service beyond their original design life of about 40 years and are a vital component to Ontario's power grid. To safely maintain an electricity network, which serves nearly 1.4 million customers and covers approximately 75 percent of the geographic area of Ontario, inspection, and maintenance of transformer bushings is essential to the power security of the province.

System safety, yet optimizing resources for upgrading and maintaining transmission systems is of critical importance. The costs associated with a failed transformer go beyond the equipment replacement costs, but also extend into the system outage costs, cancelled maintenance costs and the costs to adjacent equipment, which now must pick up the load while waiting for equipment to be replaced or repaired. Hydro One uses a proactive strategy to maintain transformers through regular inspection, repair, refurbishment and replacement programs. The goal is to service existing assets before a costly failure and to have an inventory of spares available to reduce wait times for essential parts (Fig 1).

Fig 1 – Spare bushings at Hydro One Central Maintenance Services.

Transformer bushings, a critical component yet common cause of issues in transformers are among the most cost efficient item to maintain. Hydro One maintains an inventory of 1000's of previously used and refurbished transformer bushings, ready to be tested and re-used to reduce the duration of emergency and maintenance outages by providing immediate replacement bushings to our existing in service transformers. In addition to reducing lead times compared to ordering new bushings, refurbishing bushings reduce the environmental impact by diminishing the amount of disposed equipment and normally present an economical benefit of lower overall replacement costs.

In 2019, Hydro One overhauled over 200 bushings, allowing these bushings to be available for future use and preventing them from entering landfills.

BUSHING INSPECTION

Transformers and breakers are among the vital equipment found in electrical stations and need to be maintained and inspected on a regular basis. Bushings allow electricity to flow from the overhead bus work into the station transformers and breakers and are an essential component to that equipment. Maintenance and inspection of transformer and breaker bushings are an economical method to extend the service life of station equipment.

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When a bushing is installed in a transformer or breaker, as illustrated in Figure 2, only the top half of the bushing is visible as the lower portion is hidden within the equipment. Visual inspections in the field should check for surface damage such as cracks or chips to the porcelain. On brown porcelain, cracks are easily seen as white lines, the colour of the porcelain below the coating.

When a bushing is removed from equipment or brought back to the lab for testing, it should also be checked for missing parts, oil leaks and damaged surfaces.

Fig 2 – Bushings installed on a transformer.

BUSHING TESTING

As a critical component to electrical equipment, bushings must be tested to ensure they still meet their electrical requirements. Bushings may be tested either while installed in equipment or removed and supported on their own (Fig 3).

At Hydro one, bushings are tested for high voltage insulation test capacitance, dissipation factor and power factor. In addition Megger test and micro-ohm tests are completed. The test results are then compared to the bushing nameplate value to determine if the bushing is still performing as required. In some instances, only partial nameplate values are available and these bushings must be compared to historical test results, either on similar bushings or on past testing of the same bushing. If a bushing has a significant change in either power factor or capacitance over time, it is either re-tested (extreme humidity can effect test results), overhauled or scrapped.

Fig 3 – Bushing testing at the central maintenance services at Hydro One.

BUSHING REPAIR AND REFURBISHMENT

When a transformer or breaker bushing is found to be defective, the costs of refurbishing an old bushing has been found to be significantly less than purchasing a new bushing. Furthermore, finding acceptable replacement components on some of the old electrical equipment has been challenging and their lead times can be several months for a replacement bushing. Not to mention, refurbishment of an old bushing reduces the environmental impact by diminishing the amount of old equipment sent to landfill.

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This paper will focus on a typical bushing overhaul, and not specifics of individual bushings.

After a bushing arrives at Hydro one, the bushing is placed vertically on a stationary steel rack (Fig 4) and visually inspect for any cracks, chips, oil leaking, other visible damage or mission parts.

After the bushing has been visually inspected, it must be lifted using the correct size lifting eye (Fig 5) and an overhead jib crane (Fig 6) and placed horizontally in the vice (Fig 7).

Fig 5 – Lifting eye. Victal [1]

Fig 4 – Visually inspect for damage or oil leaking.

Fig 6 – Lift bushing with lifting eye.

While in the vice, the bushing must be protected from the clamp with a nitrile rubber wrapped around the core of the bushing. Considering the top weight of the bushing and not to tip over, it is recommended to clamp the bushing approximately one inch below the flange and possibly support to top load with a strap. In order to drain the oil from the bushing, a bucket should be placed under the top end of the bushing, and the drain plugs removed, allowing oil to drain out Fig 7.

Fig 6 – Bushing in vice

Fig 7 – Drain oil from bushing

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Once most of the oil is drained from the bushing, the top nut as illustrated in Figure 8, including the O-ring, beveled washer (Fig 9) and porcelain may be removed from the core and stored on a work bench and in marked containers.

Fig 8 - top nut on bushing loosened

Fig 9 - Bevelled washer

After the porcelain is removed, the ground continuity screw, O-ring and spring may be removed as illustrated in figures 10, 11 and 12.

Fig 10 - Remove ground continuity screw

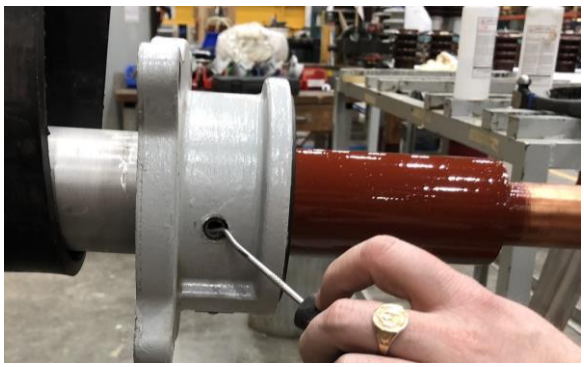

Fig 11 – Hook to remove the spring

Fig 12 – Spring in flange

Continuing to disassemble the bushing, the flange may be removed from the core and also placed aside for storage (Fig 13).

Finally after all pieces have been removed and safely stored in a container, the bottom connecting ends are also removed and stored away for cleaning as illustrated in figures 14 and 15.

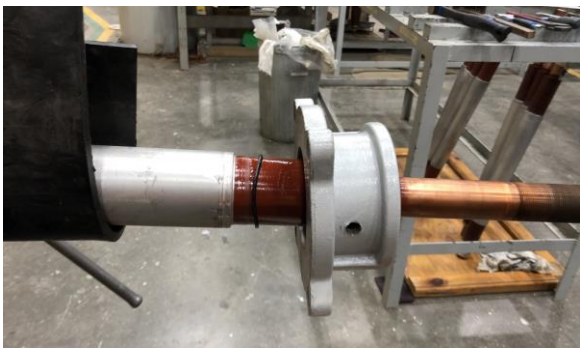

Fig 13 – Removing the flange

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Fig 14 – Removing the bottom connecting end

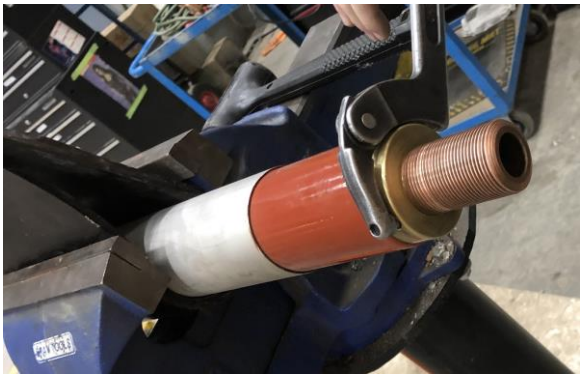

Fig 15 – Base of the bushing core

Fig 16 – Core stored on rack

After the bushing is completely disassembled, the individual pieces of the bushing need to be cleaned and repaired. Top and bottom connecting ends are scrubbed with abrasive pads or with a wire brush and the resin core is cleaned and any scratches or chips repainted. After any painting has cured, the core is moved to a stationary rack, as illustrated in Figure 16, and stored on a wood plank while the individual pieces are overhauled.

Finally, metal pieces such as the top nut, beveled washer and flange are sand blasted and polished or re-painted. Dust and residue from the flange and other small crevices are cleaned with a pressure hose and solution.

The porcelain is then polished and all residue is removed from both the inside and outside (fig 17). The porcelain is inspected for minor damage, small cracks and chips are repaired with epoxy bond putty.

Fig 17 – Porcelain waiting for inspection

New O-rings and gaskets are precision cut by hydro one staff at the central maintenance services (fig 18) and glued onto the top flange and porcelain. All parts are wiped clean one last time and the bushing is ready to be reassembled.

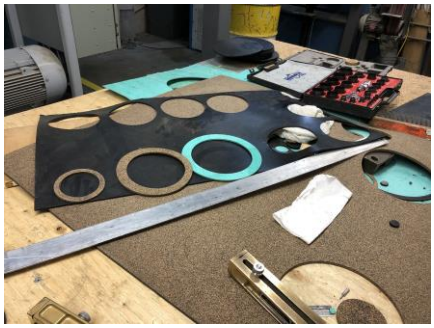

Fig 18 – Cutting new O-rings

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After the bushing has been re-assembled, the bushing is filled with 3-6 psi nitrogen gas and check for leaks around the top nut, beveled washer or any sealed surface. If there are any leaks, re-check the assembly and ensure all pieces are aligned and assembled properly. When no leaks are confirmed, the bushing is ready for vacuum and then filled with oil.

After all bushings are overhauled, it is imperative to ensure they meet all electrical requirements. Hydro one staff perform another high voltage insulation test – capacitance, dissipation factor and power factor and compare the results with bushing nameplates or historical bushing data. Bushings that pass all electrical requirements may then be returned to service or stored and ready as emergency replacements.

DISCUSSION

Scheduled maintenance and emergency repairs on electrical equipment requires station outages, resulting in system outage costs and additional loading on adjacent equipment. The longer the duration of the outage, the greater the costs may be. Hard to source replacement parts on old infrastructure can result in long lead times, also increasing the duration of the outage.

In 2019, Hydro One overhauled over 200 bushings and then compared the cost of an overhauled bushing to the cost of a new replacement bushing. It was determined that on average, the cost savings of overhauling a bushing ranged from $200 to $3000 compared to purchasing a new bushing. Furthermore, the standard lead time of replacement bushings was approximately 81 days, compared to a bushing overhaul that can be completed in a few days, resulting in less outage time required during emergency repairs or scheduled maintenance.

CONCLUSION

Highly trained Hydro One staff have gained the technical expertise to inspect, test and overhaul both transformer and breaker bushings.

Hydro One has found that overhauling transformer and breaker bushings results in a significant cost and time savings over purchasing new replacement bushings.

BIBLIOGRAPHY

[1] Victal, I. (2019), “LV Bushing Overhaul”, Hydro One work instructions

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