Technical Bits … *of knowledge*

High-Voltage Oil-Filled Bushings – TB004

The industry has experienced a rash of high-voltage oil-filled bushing failures, specifically at voltages 230 kV and up. The failure of a high-voltage bushing is not only detrimental to the major apparatus where the bushing is mounted, but it is also detrimental to adjacent pieces of equipment as well as to the safety of personnel. Recent failures have shown that the energy dissipated during a high-voltage bushing failure can be so great such that large pieces (up to 6") of porcelain bushing housing were found as far as 100 yards away from the failed bushing.

Consider the precautions taken when shipping a large power transformer. The transformer is equipped with impact recorders attached to detect impacts that the transformer may have been exposed to. When the transformer arrives on site, several tests are performed to determine proper shipment. These tests include:

- Visual inspection
- Verify main tank has positive pressure
- Core ground Megger test
- Dew-point or oil analysis (depending if the unit was shipped filled with dry air or oil)

Finally, when the transformer is assembled, a number of additional tests are performed including:

- Doble power factor
- Sweep frequency response (SFRA)
- Transformer turns ratio (TTR)
- Winding resistance
- Insulation resistance
- Oil analysis

The bushings for the above mentioned transformer are typically packed and shipped separately in shipping crates. The bushings are packed and set at an angle (with the crate in a flat position) in a way such that the bushing core is always covered with oil. This prevents the crepe paper in the bushing core from drying and losing mechanical and electrical strength. Another important function of storage/transport of a bushing at the proper angle is to keep air bubbles from reaching and being trapped in high electrical stress areas of the bushing core. However, there are no controls to ensure that the crates are actually shipped and/or stored in a flat orientation, nor is there a mechanism to determine if the bushings were subjected any mishandling (i.e. dropped, flipped, inverted, etc). Once on site, the bushings are typically only Doble power factor tested. Aside from the Doble tests and a visual inspection, no other tests are performed on the bushings prior to energization.

For these reasons, extra precautions should be taken when installing, testing and maintaining high-voltage bushings. The bushing manufacturer will typically specify the time required for the bushings to rest in the

vertical position before any voltage is applied (this includes test voltages). Additionally, the bushing manufacturer will typically also provide instructions for storage of the bushings. Some bushing manufacturers require the bushings to be stored vertically, if storage is to be long-term. Other manufacturers allow long-term storage in the original shipping crates (which support the bushing at an angle to keep the bushing core covered by oil). Bushing manufacturers may also specify a maximum storage time period. If the storage time period is exceeded, the manufacturer may recommend returning the bushing to the factory to repeat the high-voltage tests before the bushing is placed into service. Some bushing manufacturers allow/recommend DGA testing of the bushing oil. This test provides an initial benchmark to detect overheating, partial discharge, and arcing internal to the bushing after the bushing has been in service.

There are several types of on-line monitoring equipment available to detect early stages of bushing failure including on-line power factor / capacitance monitoring, on-line partial discharge monitoring, and on-line transient overvoltage monitoring. Another very useful tool for monitoring bushing health is infrared scanning. This is a relatively inexpensive test that is performed while the bushings are energized and preferably at full load. The infrared scans can detect hot spots associated with loose connections, low oil levels and in some cases partial discharge and internal arcing.