Bushing Monitoring

More than just a sum current!

Role and value of bushings

Without bushings, key elements of the electric supply system, such as power transformers and circuit breakers, would not operate effectively or efficiently. A bushing is simply a device that allows a conductor to pass through a barrier: it has an insulating medium, which must be sustained to prevent the passage of excess current to ground. Bushings are a bit like the tires on your car: they enable the car to do what it is supposed to do, but are not the reason why you buy the car - they are enablers, and when they fail the results can be catastrophic.

Bushings are not perfect!

Bushings are not perfect and do allow a current to flow through the insulating medium to ground – the bushing leakage current. The Doble IDD™ measures and records the leakage current, including magnitude, harmonic content and relative phase of the leakage currents in a set of three bushings; these provide information about the state of bushing insulation.

Idealized Leakage Currents

Ideally, each leakage current in a set of three would be a sine wave, all three of identical magnitude and be separated by 120º phase difference. This would mean that their sum would be zero – but this is rarely the case, as is shown in Figure 1.

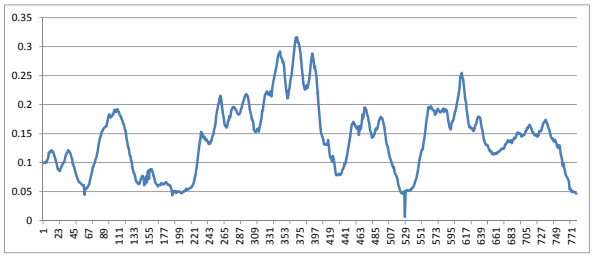

Figure 1 Sum Current for Real Bushings

Here the sum of currents is clearly non zero – but is 'normal' for this set of bushings. Variation in sum current may be caused by system voltage variation on each phase, by thermal effects and by the differences between non-identical bushings. Doble used the sum current over a decade ago as indication of a deteriorating bushing, but we moved away as it can be misleading, resulting in many false positives from a monitoring system.

Analyzing individual currents, and the raw data which gives the currents provide much more information. Doble IDD™ applies an expert system to learn what is normal at each set of bushings; in addition, limit values are set which provide a means to identify insulation degradation.

When bushings go bad

As the insulation in a bushing degrades, the current changes. It may increase in magnitude and it may change in power factor. When measuring the current it is important to look at both the resistive and capacitive (reactive) components of the current – for which we need the individual current magnitudes and relative phases. Figure 2 shows the actual currents and relative phase measured on three in service bushings.

Figure 2 Actual Currents and Relative Phase

The currents are clearly not sinusoidal, and clearly not equal magnitude – yet this is normal for this location. Doble's expert system learns this and identifies where variation occurs, picking out trends on daily, weekly and monthly bases.

It is possible to measure a bushing capacitance, using a balanced bridge approach – but this misses much of the data needed to make a clear analysis of a bushing: the current and the relative phases of the currents. The leakage current is a vector, not a scalar, and must be treated as such by the expert system.

Doble Experience in Monitoring Bushings

With over 2,000 Doble IDD ™ systems installed around the world, and over 10,000 bushings

monitored, Doble has gained great experience in what is needed to monitor bushings successfully and provide early warning of incipient failure. Many of these are documented in Doble Conference papers, published by Doble IDD ™ system owners where a bushing has been saved.

Examples of Documented 'Saves'

Graceful failures are ones which give plenty of warning of impending bushing failure – ideally weeks to months of advance warning so replacement bushings can be identified and strategically placed to be used at an opportune moment before failure occurs. Figure 3 shows where a bushing power factor deteriorates over several weeks before being removed from service in a controlled manner.

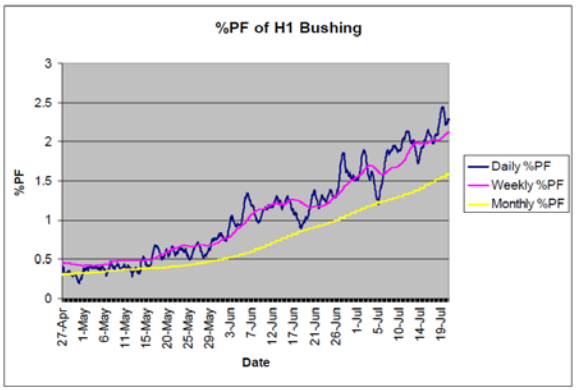

Figure 3 Power Factor Deterioration

Capacitance measurements and sum currents may miss this type of deterioration, which was subsequently confirmed by off line tests and bushing tear down..

Rapid failure may occur in as little as a few hours. At the 2013 Doble Client Conference, a paper was presented which showed a leakage current magnitude variation which took place and was indicated by the Doble IDD ™ expert system[1]. The bushing was removed and condition confirmed through off line tests and subsequent tear down. The owners of the transformer had planned ahead – when the IDD gave its most urgent alarm an 'action' setting, they implemented a plan to remove the transformer from service within two minutes. They saved the bushing and the transformer; two months later they had an identical save on a similar bushing.

Data & Timeliness of Information

To make good decisions needs a foundation of the most comprehensive data possible. For bushing measurements it is important to have the raw sinusoidal waveforms available, to have magnitude of individual currents and relative phase and to have an expert system analysis which learns what is 'normal' at an individual location.

The nature of bushing failures is that they may be very rapid – an agreed plan to act on the data and warnings generated is vital to getting the most from a monitoring system.

Adding Partial Discharge

The Doble IDD ™ ha proven itself in many locations and in many applications. It is possible to add a Partial Discharge monitoring system to a Doble IDD ™. If Partial Discharge is a possible cause of insulation deterioration, or a symptom, then we recommend that intermittent PD testing of the bushing currents be undertaken with reference to main tank UHF PD probes and neutral current monitoring. If warranted, we recommend installing Doble's "PD Guard +" monitoring system.

Conclusions

Bushing monitoring requires appropriate data in depth and with built in expert system analysis. This means more than just a simple capacitance measurement or sum current approach. Good data yields good decisions, as has been documented through bushing saves published at the Doble Client Conference and elsewhere.

[1] "Condition Monitoring in the Real World", G. Mackay, Transgrid, Australia, Doble Client Conference, USA, 2013

Doble Engineering Company
Worldwide Headquarters
85 Walnut Street
Watertown, MA 02472 USA
tel +1 617 926 4900
fax +1 617 926 0528
www.doble.com