TLM: Transformer Life Management Bulletin

Transformer Core Demagnetization

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Residual magnetization is caused by steel in the magnetic core holding on to magnetic polarity due to the tendency of any magnetic material to store energy. Interruption of normal AC excitation, DC winding resistance testing, tripping of the transformer, and geomagnetic phenomena can be sources of residual magnetism.

The condition of residually magnetized core is not a failure as such. However, it may result in elevated and thus potentially damaging inrush currents (which exceed the transformer's rated current by an order of magnitude and more) when the transformer is energized. The in-rush currents cannot be avoided unless the excitation is applied at a precisely known instant of time to a transformer core with precisely known magnetized state. However, in practice the transformer is energised in a random part of the AC cycle and thus making sure that the core is demagnetized is advantageous. It greatly reduces the risk of a worst-case scenario when an already magnetized core is pushed even further into saturation and the resulting in-rush current is significantly increased.

A large in-rush current carries multiple implications but to the transformer itself, the high mechanical forces and resulting vibrations due to these currents may cause increased wear on the insulation of transformer windings. For the power system, protective relays may not distinguish between causes of high current (e.g., a transformer fault or in-rush current due to a magnetized core) and will trip until this condition is corrected. The resultant uncertainty created when a transformer trips may spur what turns out to be an unnecessary (if due to in-rush current) follow-up investigation that consumes significant time and resources. A magnetized core may also influence certain off-line, diagnostic test results such that meaningful conclusions about the condition of the transformer cannot be accessed.

Residual magnetization can lead to lower as well as higher magnetizing inductance during testing. Results from tests in which none of the transformer windings are short-circuited may be notably impacted, particularly exciting current and Sweep Frequency Response Analysis (SFRA) tests. For exciting current measurements, a magnetized core usually results in higher amplitudes (due to lower inductance) and disruption of the expected (e.g., low-high-low or high-low-high for Phase 1, 2, and 3) measured current and watts "phase" pattern of three-phase transformers.

For SFRA measurements, lower magnetizing inductance due to a magnetized core will result in an increase of the amplitude at lower frequencies and also a shift of the first main resonance in the FRA curves. [Note that a larger inductance pulls the response's amplitude down in dB earlier than a comparatively lower inductance (such as in the case with a magnetized core) will; just like a larger capacitance will cause the amplitude response to "climb back" towards 0 dB quicker than a comparatively smaller capacitance will.] This is illustrated in Fig. 1 which gives SFRA measurements before and after demagnetization of the same transformer.

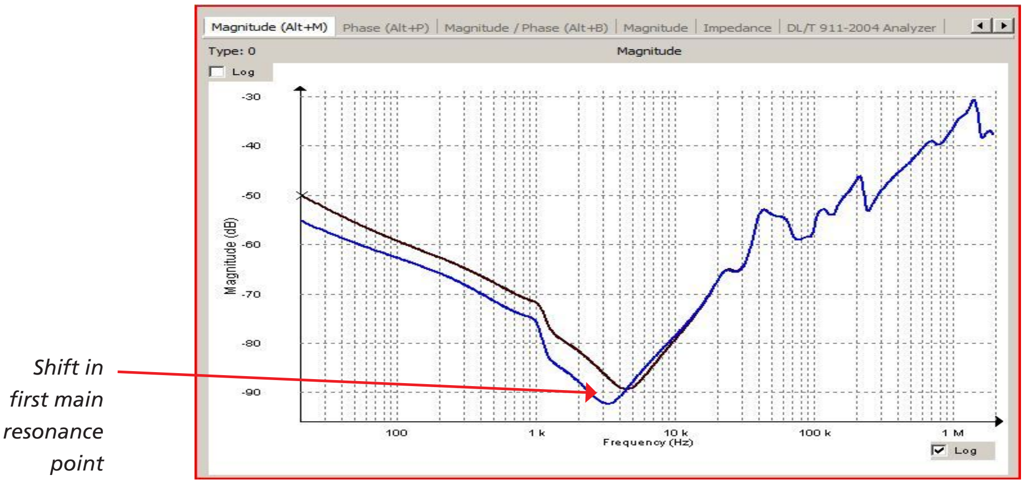

Fig 1. SFRA response for magnetized (black) and demagnetized (blue) transformer

Core steel will hold some magnetic polarity unless action is taken to neutralize it. It is not possible to demagnetize a transformer simply by allowing it to sit de-energized for long periods. Interestingly, once demagnetized, the transformer core will not indefinitely remain in that precise neutral state. Residual magnetization may vary over time due to the so-called ***magnetic viscosity***. It has been observed that any sudden change of excitation field (applying or removing magnetization current) yields a slowly varying magnetic relaxation, which causes the impedance to change with time due to magnetic viscosity. Therefore, even when no DC excitation takes place, an SFRA response may shift between tests at low frequencies and the amplitudes of exciting current measurements may not be the same from one test to the next (although in these cases, the expected "phase" pattern, e.g. H-L-H, is typically preserved).

Transformer Core Demagnetization

Because some legitimate problems affect exciting current test results and SFRA results in a similar fashion as core magnetization, residual magnetization needs to be ruled out as the culprit when test results are affected as described above.

It is recommended to demagnetize the core after performing DC winding resistance tests (which require saturation of the transformer core, and in any case will leave the core in significantly magnetized state) or any other test that may cause magnetization. A good practice is to demagnetize the transformer before any tests are performed and also demagnetize after tests are completed and before the transformer is energized. It is important to apply demagnetization before the tests because disconnection of the transformer from AC excitation usually happens at a random instant of time and thus some random level magnetization remains in the core. With the ability to easily and efficiently demagnetize a transformer, the long held testing rule to perform winding resistance test measurements last in a sequence of tests may eventually be upended.

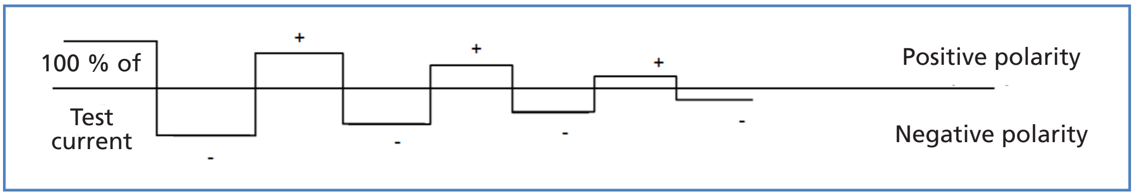

Fig 2. Demagnetizing sequence of a switched DC source.

On-site demagnetization of power transformers is most often accomplished by using the DC method of alternating polarity current or voltage pulses. The principle of an alternating direct current method is to neutralize the magnetic alignment of the core iron by applying a direct voltage of alternate polarities to the transformer winding for decreasing intervals. The alternating DC injection is reduced for each cycle, typically by 10 to 50%, and the process is continued until the current level is practically zero. On three-phase transformers the usual practice is to perform the procedure on the HV phase associated with the highest exciting current reading. In most cases, experience has demonstrated that this procedure is sufficient to demagnetize the whole core. Depending upon transformer design (e.g., 5-legged versus 3-legged core), size, and test instrumentation capability, performing several demagnetization attempts and/or on different terminal pairs may sometimes improve demagnetization. Most instruments today apply switched DC current for demagnetization as shown in principle in figure 2.

A variant of the above is to inject current by applying voltage until the defined current is reached (typically the same value as the test current, e.g., 10 A) and the core is saturated. This gives the volt-seconds (Vs) from starting point to saturation in the positive direction (e.g., 200 Vs). The procedure is repeated in the opposite direction (e.g. to -10A). The required Vs from e.g. +10A to -10A is measured/calculated (e.g. -1000 Vs) from which the Vs-positions of the "tips" of the hysteresis loop may be determined. In this example, Vs-position at -10A is -500 Vs and +10A is at +500 Vs. The origin of the hysteresis loop and goal is at 0 Vs and the starting point in relation to this can be calculated; e.g., starting point is at +300 Vs (+500 VS – 200 Vs). In Figure 3, which gives a screenshot of this demagnetization method once completed, the starting point has been determined and is provided to the tester by a red dot in graph. For each subsequent repetition, the volt-seconds applied to the winding is decreased by typically 10-50%. In practice this becomes a Constant Voltage Variable Frequency method (CVVF).

The before and after values as Vs or % of saturation are provided as given by Figure 3.

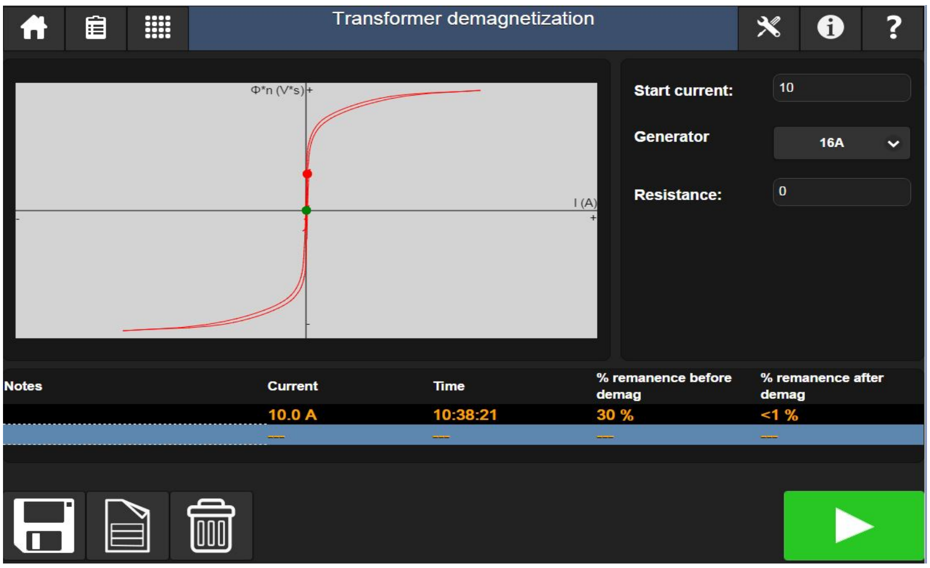

Figure 3. Megger TRAX multifunction substation test instrument - transformer demagnetization screenshot

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In cases where the trigger for demagnetizing a transformer is an investigation into exciting current, SFRA, and/or magnetic balance test results, which are believed to be affected by core magnetization, verification that the demagnetization attempt was successful is provided through the return to expected results. Otherwise, it is unnecessary to perform verification each time the transformer is demagnetized.

A number of international standards and guides describe how, why and when the transformer should be demagnetized and how a magnetized core can affect measurements results, e.g. IEEE C57.152, IEC 60076-18, IEEE C57.149, CIGRE TB342, and CIGRE TB445.

All Megger winding resistance test instruments and multifunction instruments with winding resistance test capability have a built-in demagnetization function. The effectiveness, efficiency, and safety of an automated demagnetization feature can vary between manufacturers so a user is advised to not assume that all are created equal.

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