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INTERPRETATION METHODOLOGY TO IDENTIFY FAULT LOCATION IN A POWER TRANSFORMER

Sameer S. Patel[1],

[1] Student, Electrical Dept, Rajasthan Institute of Engineering and Technology, Jaipur

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Abstract - *FRA is a comparative method for assessing the condition of power transformers. To evaluate the FRA results, actual data are compared with reference data either by direct visual inspection of the curves or by using processed FRA data. There are three approaches for generating reference data:*
(1) previous fingerprint measurements on the same unit;
(2) Measurements on identical (twin) transformers;
(3) Measurements on separately tested limbs or phases (Phase to Phase Comparison)

Key Words: Comparison Method, Fault Location, Graphs, SFRA Kit, Connection Lead, SFRA Traces

1. INTRODUCTION

Sweep frequency response analysis is a major advance in transformer condition analysis. Frequency response is performed by applying a low voltage signal of varying frequencies to the transformer windings and measuring both the input and output signals. The ratio of these two signals gives the required response. This ratio is called the transfer function of the transformer from which both the magnitude and phase can be obtained. Changes in frequency response as measured by SFRA techniques may indicate a physical change inside the transformer, the cause of which then needs to be identified and investigated. We are identifying using comparisons methods after fault created in transformer.

2. EVALUATION BY FINGERPRINT RESULTS

The fingerprint test data set is potentially the most reliable reference information for evaluating FRA tests. Assuming a high repeatability of the test technique, it is possible to obtain almost identical FRA results. An example would be two scans collected from the same winding, such as H1-H3, on different test dates. Data is collected before and after transformer relocation is expected to overlay well. Any variance is such comparisons indicate a problem. One exception is caused by the magnetic circuit and the state of the remnant magnetism occurs at low frequencies and should be overlooked. Magnetization and temperature change can cause the beginning of the trace to be slightly offset in certain cases. Fig. 1 illustrates a before and after relocation response of a set of high-voltage windings. The results were not only obtained on different test dates, but also were obtained with different test sets. Phase to phase variations exist, but there are no differences before and after relocation.

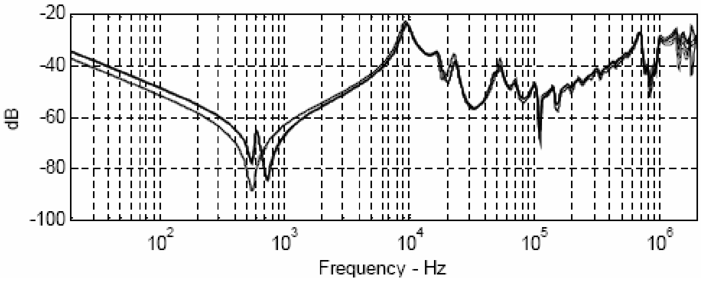

Fig.1 Comparison to Baseline

It should be noted that the LTC and DETC position influences the results. If the test results are obtained in different tap positions, expect variation. Fig. 2 shows two traces collected in different tap positions; the difference is small, but noticeable at frequencies greater than 500 kHz. The DETC was moved from position 3 to 5.

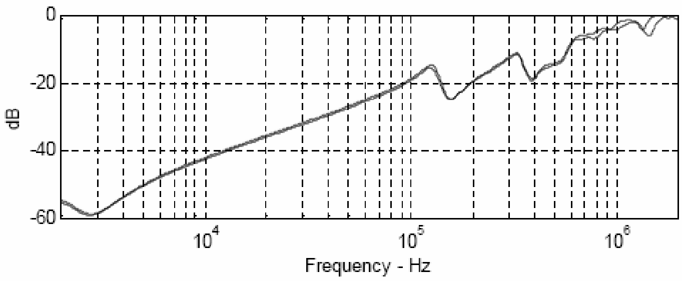

Fig. 2 Different DETC Positions (3 & 5)

3. COMPARISON OF TWIN AND SISTER TRANSFORMERS

Fingerprint results are not always available for FRA evaluation of FRA results. Sometimes, customer orders include several transformers of identical specification so that finally transformers of identical design are operated within one power grid. Identically designed and identically assembled transformers (twins) typically show almost identical FRA curves. Slight deviations between twin transformers are generated exclusively by manufacturing tolerances and/or core magnetization effects. (Fig. 3).

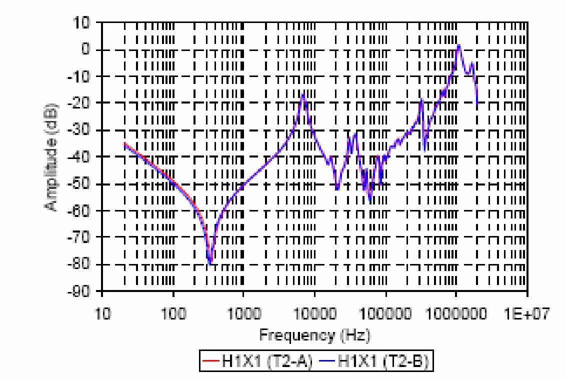

Fig. 3 FRA of real twin units

Sister unit results are also expected to compare well. Our database of sister units shows very little difference between matched scans. All tests on sister units were conducted with the LTC and DETC in the same position.

If the results are magnified small offsets can be noticed, but for the most part they are similar. Fig. 4 demonstrates the similarities of sister units. Each plot consists of two high voltage winding traces and two low-voltage winding traces.

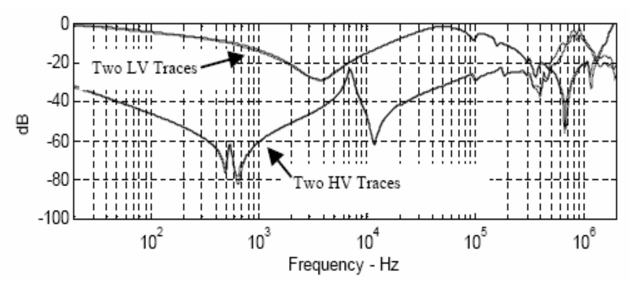

Fig. 4 Comparison of Sister Units

The applicability of FRA interpretation based on a sister unit comparison therefore has to be validated. It is quite difficult to discern real twin transformers from sister units. Some parameters for identifying twin units are given by:

- Manufacturer
- Factory of production
- Original customer/technical specifications
- No refurbishments or repairs
- Same year of production or +/-1 year for large units
- Re-order not later than 5 years after reference order
- Unit is part of a series order (follow-up of ID numbers)
- For multi-unit projects with new design: tested transformer is not first, second or third unit.

The more indications are positive, the more certain is similarity of core-and-coil Assembly.

3.1 Sister power transformer graphs for advantage to identify of fault location.

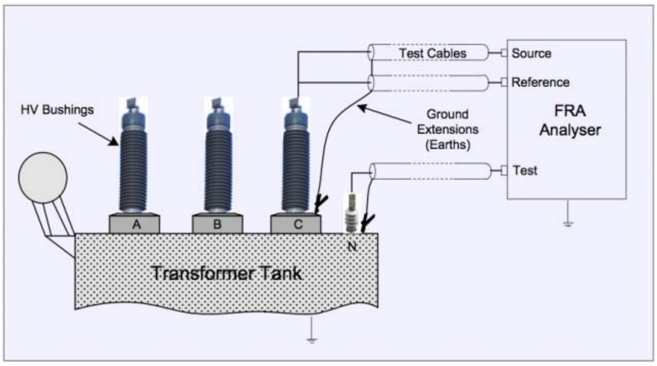

Fig: 5 SFRA test connection lead for transformer

In transformer, if YNyn0, source and reference cable connected on 1u of phase winding and second lead earthed also. When test probe connect neutral as same as previous connection lead diagram.
Then, see, figure 6, and figure 7 connect cables, test configuration about data transmission cable, laptop parameter etc.

Precaution where operate this kit,

- Check circuit or connection cables
- Connect circuit via laptop key F2
- First of all use calibration graph for connections are well.
- Earthing should be tight.

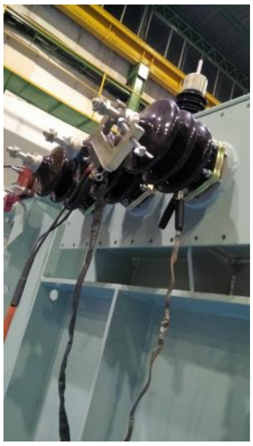
Fig: 6 bushing connection lead for transformer


Fig: 7 SFRA kit

3.1.1 Case-1

JN: 22579/1, 132/33 KV, 40-50 MVA BASED

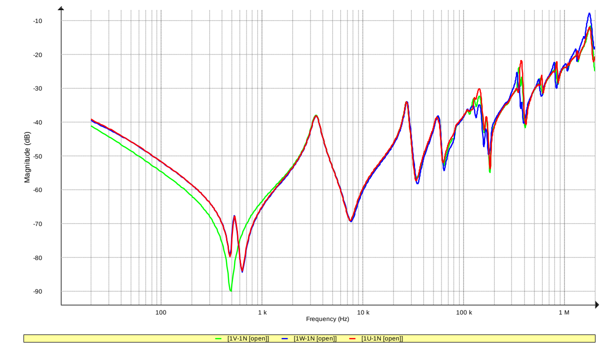

Fig: 8 applied on HV & LV OPEN Graphs

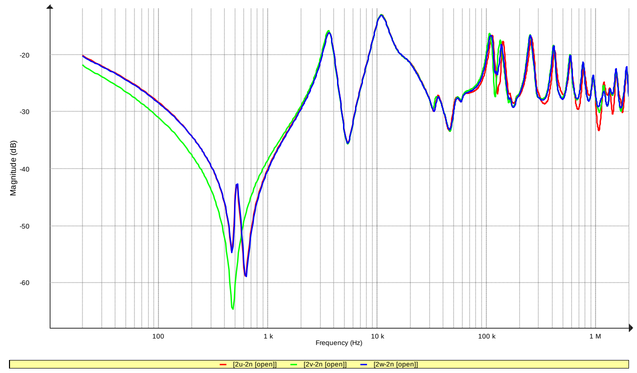

Fig: 9 applied on HV & LV are SHORTED Graphs

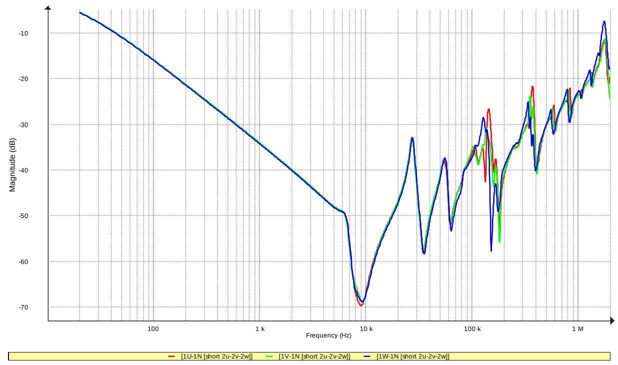

Figure: 10applied on LV & HV OPEN Graphs

3.1.2 Case-2

JN: 22579/2, 132/33 KV, 40-50 MVA BASED

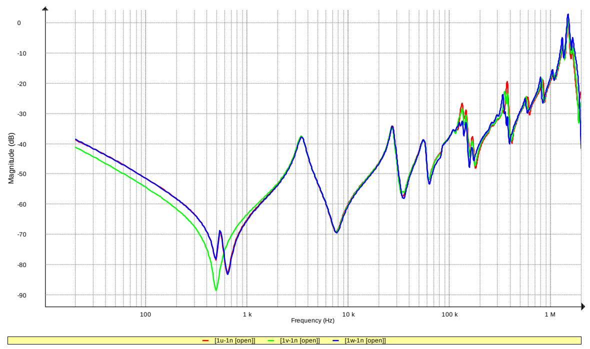

Fig: 11 applied on HV & LV OPEN Graphs

We are checking SFRA graphs plotting on tap number 1(On Load Tap Changer) for a full winding measurement for HV for HV variation power transformer.

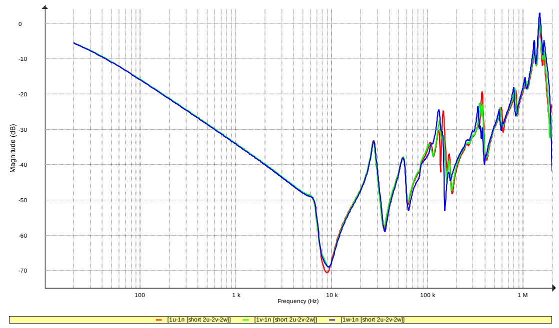

Fig: 12 applied on HV & LV are SHORTED Graphs

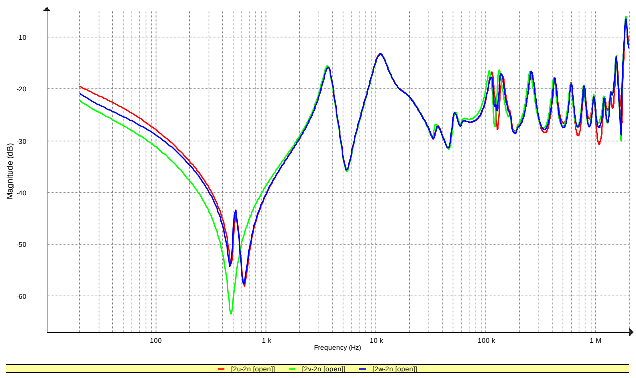

Fig: 13 applied on LV & HV OPEN Graphs

4. PHASE TO PHASE COMPARISONS

Many times for old transformers when reference signature is not available the first step is to compare the signatures of phases of the transformer. It means comparing the signatures of phase U with phase V and phase W.

It is assumed that for majority of cases there would be good matching between phase U and phase W as they are symmetrical being on extreme limbs.

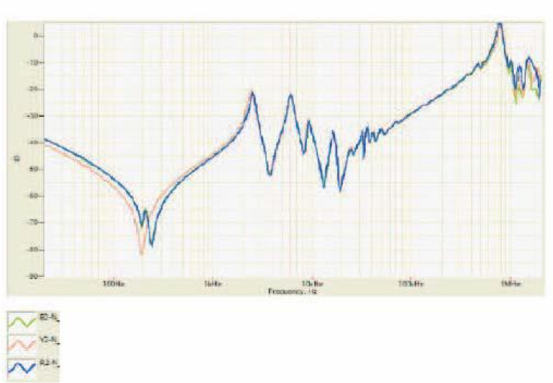

Fig. 14 Three Phase SFRA comparison for open circuit plot of normal transformer

Whereas phase V (Center phase) would not be matching with the other two phases particularly in the region 10Hz to 2kHz as the magnetic path for the center phase is different. In phase to phase comparison, the signatures obtained after short circuiting other winding of the transformer on the same limb, compares well as the effect of core is eliminated. Typical examples are given in Fig. 14 and Fig. 15 below.

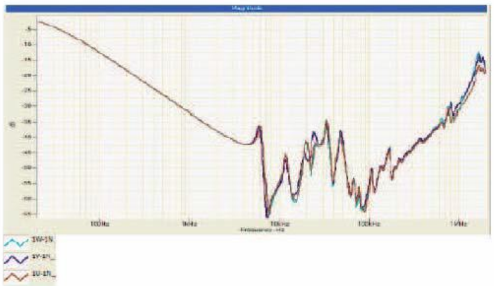

Fig. 15 Three Phase SFRA comparison of Short circuit plot for normal transformer

Open circuit responses measured after fault for the HV windings at highest tap are shown in Fig. 14. The dominant features of these plots are the first minima at low frequency near 200Hz. The position of minimum will vary somewhat depending on the remnant magnetism of relevant core flux circuits. As there is no deviation in SFRA plot after the fault among the three phases in Fig. 15, it gives indication of no sign of any winding movement.

Winding having higher impedance will attenuate the signal more at beginning of the plot. This is evident from the in general observation of the plot where starting dB level of LV winding at 10Hz frequency is (around −40dB) always lower than the dB level of HV winding at 10 Hz. (around −60dB).

Short circuit SFRA responses measured for the HV windings at highest tap is shown in Fig. 14. The dominant features of these plots are that it starts from very low dB due to shorting of the LV (2U – 2V – 2W). In this case, the low frequency minimum is not determined by low frequency open circuit inductance of winding which involve the core also. Hence it purely represents the status of winding, i.e. indication of fault like open circuit, short circuit fault etc.

Short circuit virtually eliminates the effect of magnetic core due to opposite flux of short circuit current and lowest impedance path of the shorted winding compared to core as explained. The response in band 10Hz to 2 kHz matches well for all 3 windings U, V, and W which is clear in Fig. 15.

Comparison of Open and Short circuit responses measured for the same winding at any specific tap position reveals that low frequency open circuit inductance of winding involve the core which is clear from the first minima at open circuit plot. This first minima is absent in short circuit plot due to shorting of LV winding and after 10 kHz frequency both the response are identical as indicated in Fig. 16. At higher frequencies a more complicated form of response is seen which is unique to the detailed arrangement of winding involved. This represents the fingerprint or signature of winding design involved. At these frequencies, winding inductance is dominated by leakage fluxes local to the winding conductors, and remnant magnetism of the core Has no influence.

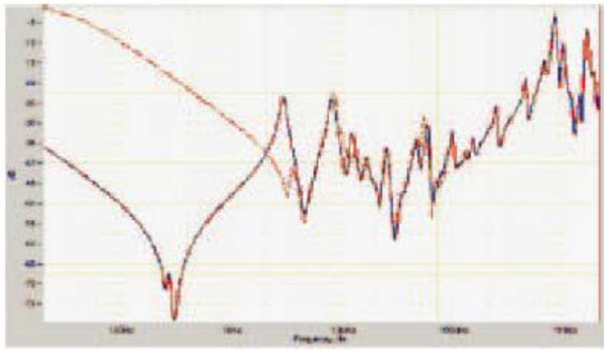

Fig. 16 Open circuit and Short circuit SFRA plot comparison of same winding for Normal transformer

However it is not necessary that the good matching that is shown in Fig. 15 and Fig. 16 would be found always. Phase comparisons are the most difficult and are open to subjective analysis. It overlays with reasonable similarity and can deviate in high frequency region.

The center phase, especially in core type transformers, exhibits the most deviation when comparing all three phases. Different flux paths seen by each phase contribute to the observed differences. The affects of the core saturation and magnetic state of the core are expected at the lower frequencies.

The actual windings of a three phase transformer are almost identical, but the connection scheme between phases is very different. As an example, the phases of a wye winding are all at different distances from the neutral and also LTC connections fall into the same category. Thus, since the windings are not equilaterally spaced, the varying lead length entering and leaving the windings, influence the individual transfer function of each winding. This would generally be found in two winding three phase transformers.

5. CONCLUSIONS

There is a learning curve associated with interpretation of SFRA traces. The traces need to be interpreted with experience, with reference to baseline results where possible, with reference to manufacturer specific variations and with reference to phase comparisons. Where baseline data is available, traces may be interpreted to look for degrees of difference. The main problem with this method is that small variations in one part for an SFRA trace may be more meaningful than larger variations in another part of the trace.

Baseline results may not always be available for a particular transformer. Here reference may be made to sister units or to transformers from the same manufacturer. Individual manufacturers may have variations that are specific to their transformers; or to compare the signatures of phases of the transformer. Phase comparisons are the most difficult and are open to subjective analysis. It overlays with reasonable similarity and can deviate in high frequency region.

When interpreting a trace, it is important to make use of all the information present to look at the whole picture. Small variations or displacements across a large frequency range may be much more important than a large variation in one part of the frequency range.

In analyzing traces, lower frequencies tend to relate to larger objects; higher frequencies relate to smaller objects. In terms of size there is a general rule of thumb that, while reviewing a trace from left to right, from 20 Hz to 2 MHz, this corresponds to the core, clamping structure and yoke, main windings, tap leads and connecting leads. The actual position of resonances in the trace depends on the size of the transformer; lower MVA transformers tend to have their resonance shifted more to the higher frequencies. However, there are always exceptions to this 'rule of thumb' and individual traces should be inspected on their merits.

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BIOGRAPHIES

Sameer Patel Doing M.Tech In Electrical Engineering (Power System) At Rajasthan Institute Of Engineering And Technology, Jaipur And Also Completed Diploma & B.Tech In Electrical Engineering.