White paper

DVtesting Reactance Tap Changers and its Diagnostics

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Introduction

DVtest or a Dynamic Resistance Measurement (DRM) testing is an off-line, non-destructive test in which a DC current is injected through a transformer winding and on load tap changer (OLTC) as it moves through all of its positions [1]. Results from the current signatures recorded with high sampling rate of 10 kHz are examined and compared against previous tests or similar unit test results. This test on an OLTC may be used to detect mechanical and electrical problems, such as tap changer slow transition time, contact problems, and open circuit, among others [2].

A reactance type tap changer is a special design where circulating current is limited by application of a preventive auto-transformer (PA). This reactor, in contrast to the resistance tap changers where this task is given to plain resistors, has dual function. By restricting short-circuit circulating current of the tapped winding, it allows operation of this tap changer in the bridging position indefinitely. Almost all of the European tap changers are of the resistance type and cannot survive operation in bridging position. Their transitions are very fast in the order of 50 mSec. In contrast to this, USA transformers use reactance tap changers for voltage regulation that are slow and provide double the tap positions (addition of bridging positions). They are positioned on the low voltage side – the LV winding.

Two distinct construction types exist: vacuum, and oil switching. The vacuum types have bypass switches and the vacuum interrupter that takes all the arcing. Oil switching models are made with arcing tap switch, or with transfer switches. While arcing tap switch executes both tap selection and switching, this task of switching is performed by the transfer switch in the later models. Now further design characteristics differentiate between: a. tap changers where both contacts are on one moving arm, like shown in figure 1 (P1 and P2) and move together; or b. where each arm carries its own contact (two arms) moves independently, but requires double the number of fixed contacts. All this makes analysis of DVtest graph very complex, and knowledge of exact design type is a must.

Figure 3 shows a schematic of a reactance tap changer with transfer switches. These open and separate contacts from the current loop, while contacts change taps. Thus, contacts last longer as they switch without carrying current. This way only the transfer switch performs all the current switching and arcing in oil.

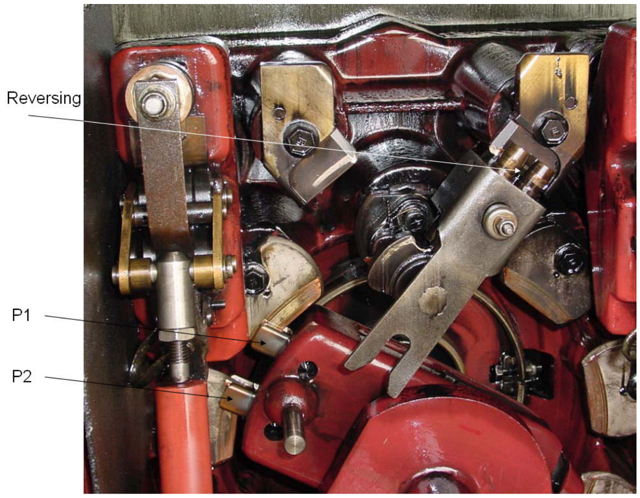

Figure 1. Tap changer with one moving arm carrying two contacts P1 and P2

DVtesting reactance tap changers

Over the last 20 years, the DVtest or a Dynamic Resistance Measurement (DRM) method was used [3] exclusively on resistance tap changers. Our experience with testing reactance tap changers is short. The method was introduced in the USA only in the last five years [1]. The DVtest current trace of the graph in figure 2 shows key points of the tap changer operation, identified by a sudden current change – the ripples.

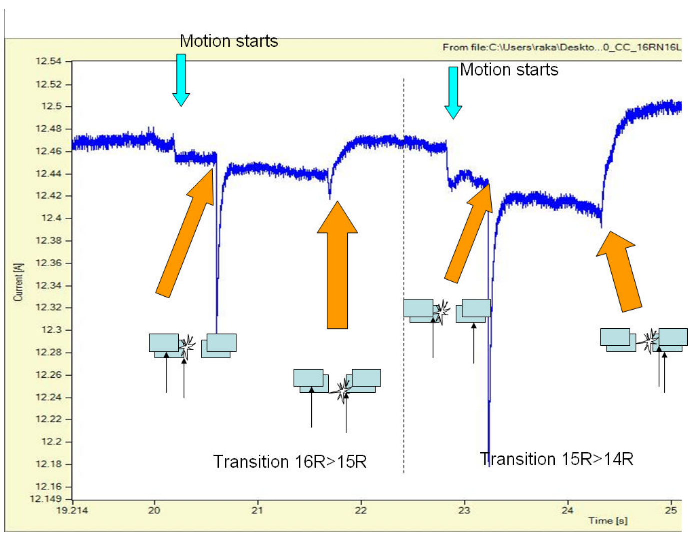

Figure 2. Reactance DVtest graph main features

The basic operation of the tap changer can be described through this example: contact P1 disconnects from tap 1, and then contact P1 connects with the tap 2. The next movement is that of the contact P2: it separates from the tap 1 and connects with the tap 2.

If we analyze this in more detail, when both contacts are in tap 1 position, we call it a non-bridging position. Let's say this is position 16R. Once the contact P1 moves to the tap 2 – this is the bridging position, and it is position 15R. Moving the contact P2 to tap 2 changes the tap to position 14R, and this is again non-bridging position. Like this, all even positions are non-bridging, and all odd positions are bridging positions. We explained earlier that reactance tap changer can operate indefinitely on a bridging position. This makes these tap changers versatile: having 2 tap positions out of 1 transformer tap.

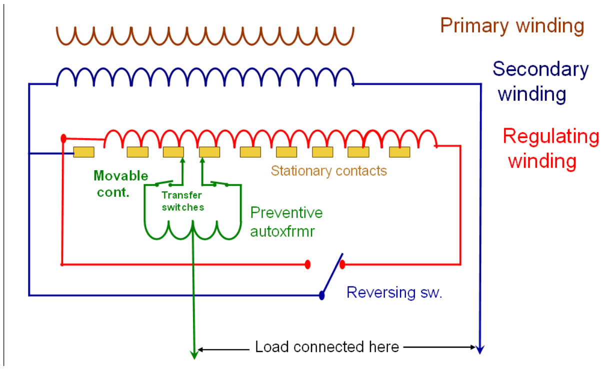

Figure 3. Reactance tap changer with transfer switches

In a DVtest graph we can observe connecting and disconnecting of contacts as large drops in current – a characteristic feature of the current trace – the Ripple. Usually ripple is bigger when the contact is separating than when the contact is making.

Characteristic ripples observed in the figure 2 show first the point when the motion of contacts starts. This is a very small ripple indicated with the blue arrow. Following is the separation of the moving contact P1 from the stationary contact 1, shown as the largest ripple; current is dropping almost vertically for a very short time and recovering as the other arm takes over conduction of the total current. The next ripple that is smaller than the "opening" one is the "closing" ripple. This is the point when the moving contact P1 makes with the stationary tap 2. During this operation the moving contact P2 does not move. As contact P2 is still at tap 1 and contact P1 is now at tap 2, this is what we call the bridging position. The second part of the graph shows motion from bridging position 15R to the non-bridging position 14R. The graph features are very similar but the big "opening" ripple is somewhat larger than the big ripple of the first transition.

For tap changers with two arms, trace in between opening and closing ripples depends only on the inductance and resistance of the transformer under test. However, the tap changer with only one arm tells us a different story. Here both contacts move together, while the stationary tap contact is wide enough for contact P1 to switch over to tap 2, while the contact P2 is still at tap 1. As the contact that did not separate and carries the current (P2) moves together with the one that opened (P1), it slides over the fixed stationary tap contact. This allows us to see the condition of these contacts based on the wiggles in the current trace.

The trace recorded when the tap changer with one arm operates is shown in the figure 4.

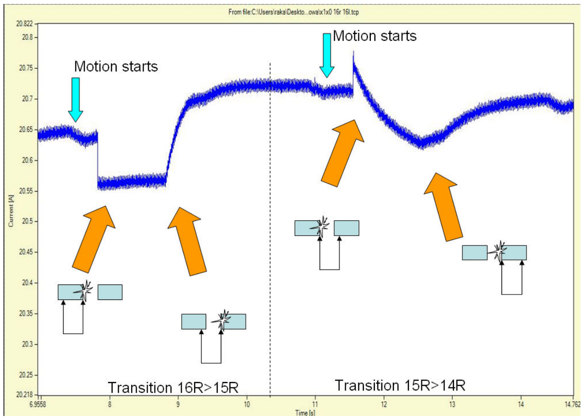

Figure 4. Trace of an one-arm tap changer

Characteristic ripples, current drops during the switching, observed in the figure 4 show first the point when the motion of contacts starts. This is indicated with the blue arrow. Following is the separation of the moving contact P1 from the stationary contact 1, shown as a big current drop; current is dropping almost vertically for a very short time and continues without change for some time. During this flat or horizontal period, the other contact P2 slides over the stationary tap, and any contact wear is observable as a wiggle instead of this nice flat line. The next ripple that now goes upwards is the "closing" ripple. This is the point when the moving contact P1 makes with the stationary tap 2. At this point we are at the bridging tap position 15R. The right portion of the graph shows transition from position 15R to 14R. In this case the trace does not look at all similar to the previous one.

In addition to this, at a vacuum type tap changer, that are two-arm types, we can observe several other feature points on the DVtest trace: moment when the bypass switch operates, and when the vacuum interrupter makes and breaks. The vacuum interrupter is operating in normally closed position, and opens only shortly during the selector transferring for about 0.5-1 sec. A typical vacuum tap changer graph is similar to the one shown in the figure 2. Big ripples represent operation of the vacuum interrupter, opening and then closing, while the small one instead of contact movement can be connected with a bypass switch opening. Typical vacuum tap changers are GE type LRT, then Westinghouse UVT, MR type RMV, and ABB model VRLTC.

Case studies

Our knowledge base contains many interesting cases where DVtest pinpointing a problem with a tap changer [2]. In this paper we will just show two very interesting findings recorded using a single phase instrument type RMO60TD [4]. One problem shows very small variation in the ripple shape, where detailed evaluation was required to observe the problem, while the other has large difference obvious at a first glance:

A case of an McGraw 394 with heavy coking on the lower stationary transfer switch of the phase X1 was detected by increased DGA ratios [2]. The exact position of the troublesome switch was indicated by carefully analyzing the DVtest graphs of the all three phases. The overlay of the phase X1 and X3 in the graph of figure 5 below shows the deviation of the blue current line (small wiggle in the red circle) pin-pointing the defect to the particular phase and operation of particular transfer switch.

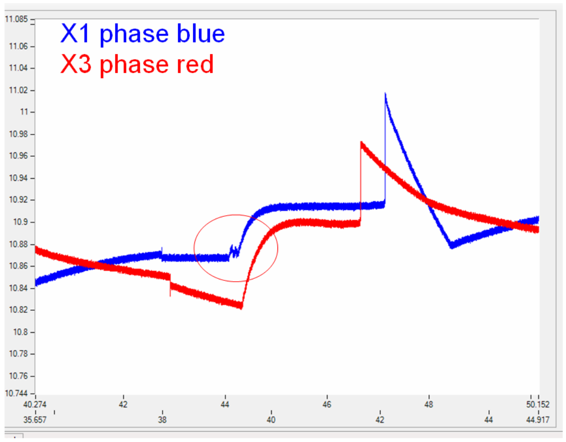

Figure 5. DVtest trace indicating coking on a transfer switch

Another case is showing a problem with FPE 546 tap changer. The bolt for the feed from the transformer to the collector ring had vibrated loose. After cleaning and retightening the bolt, a retest was performed. The graph of the figure 6 shows the difference between the phase X1 in blue and X2 in red before the repair. The larger ripple of X2 was indication that something was wrong with this phase contacts.

Following the repair a retest graph showed the X2 trace identical to the other two phases as explained in the paper [2].

When comparing the graphs, attention should be paid to the direction of tap changer motion during the test. Changing tap positions from 16L to 16R is what we call UP motion, while from 16R to 16L is direction DOWN. Traces obtained when tap changer moves up is very different from the one when it moves down, and can sometimes look like a mirror image of each other. Figure 7 shows two traces of the same tap changer in good condition, red trace was recorded in direction UP, the blue one in direction DOWN .

Special test issues

Test method may be slightly modified, i.e. the winding not-under-test can be short circuited. This makes the ripple larger as inductance restriction to a DC current is minimized due to the short circuit around the transformer magnetic core. We have seen reactance tap changer graphs with very small ripple in the order of 1% or less. Shorting the other winding makes ripple bigger and easier to observe the feature points explained before.

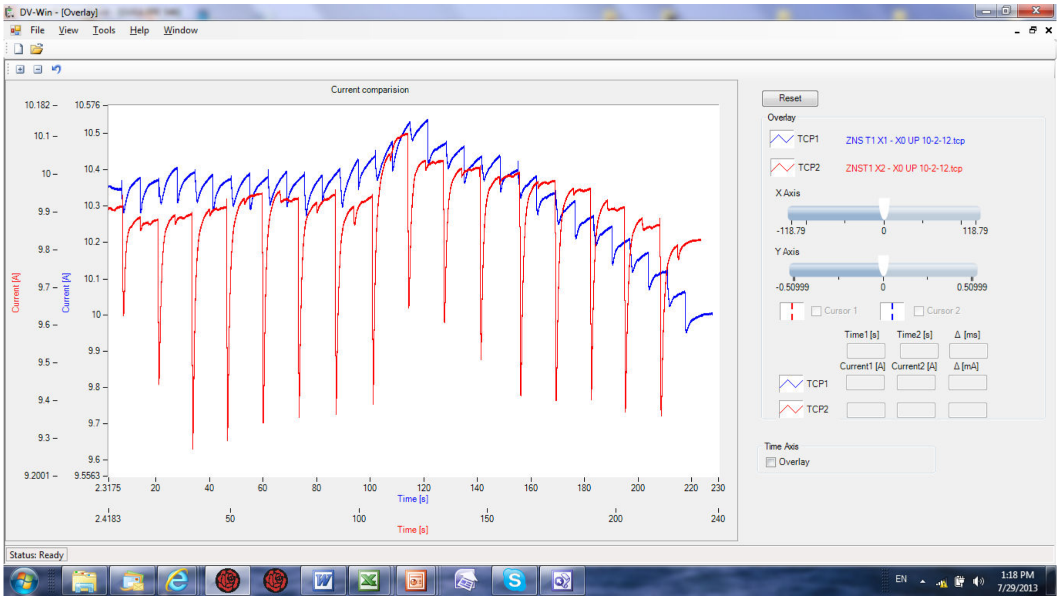

Figure 6. DVtest graph of a good and bad phase

Tap changers can be tested either in phase by phase mode, where each phase is evaluated on its own, and comparing with the others, or in synchronization mode. The synchronization mode provides a graph of all three phases at the same time and can indicate a problem if there is a time difference between phase operations. Any excessive difference is usually a sign of mechanical defect.

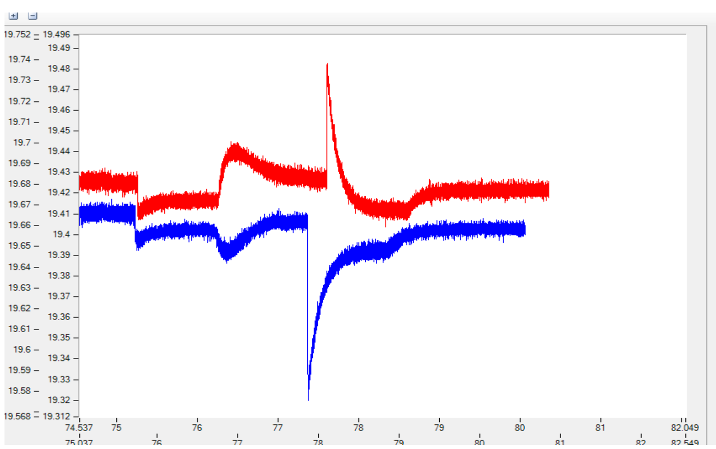
Figure 7. Two traces recorded during the tap changer operations: UP and DOWN

Conclusion

Usefulness of performing the DVtest on a reactance tap changer was shown. It can be a good diagnostic tool for condition assessment of OLTCs. Many problems can be detected including mechanical, electrical, contacts, control, etc. Note should be taken at analysis that the graphs are specific. Three important issues are observed: 1. transitions from odd to even positions are different than those when switching from even to odd, 2. design of the tap changer (one arm, or two) makes analysis different, and 3. direction of tap changer motion also creates different traces, sometimes like a mirror image.

References

1. R. Levi, B. Milovic, "OLTC dynamic testing", Proceedings TechCon USA, San Francisco 2011

2. R.Levi, G. Milojevic, "From the AMforum Knowledge-base: Case studies of OLTC problems detected by DVtest", TechCon – Training Track presentation, Sacramento CA, February 2015

3. H.F.A. Verhaart, 1995, "A diagnostic to determine the condition of the contacts of the tap changer in a power transformer", CIRED, Brussels, Belgium, paper 1.13.

4. DV Power, Instruction manual RMO60TD, Lidingo Stockholm 2015