DVtest Method Applied to Series Transformers

Abstract

Power transformers with on-load tap changer (OLTC) using a series transformer for current increase cannot be tested using any conventional methods. This is because OLTC is electrically isolated from any external points, e.g. bushings. DV Power has developed a method for the OLTC basic condition assessment. Applying the special procedure allows checking timing of the tap changer and bouncing of contacts.

Introduction

Series transformer or a booster is a separate three phase transformer placed in the tank of the large power transformer itself. It is an independent circuit, magnetically coupled to the secondary winding, and the voltage is regulated by inducing positive or negative voltage through the series transformer. The tap changer is connected to the tapped winding which is magnetically coupled to the main transformer winding. Consequently, the tap changer has no electrical contact with any of the transformer bushings.

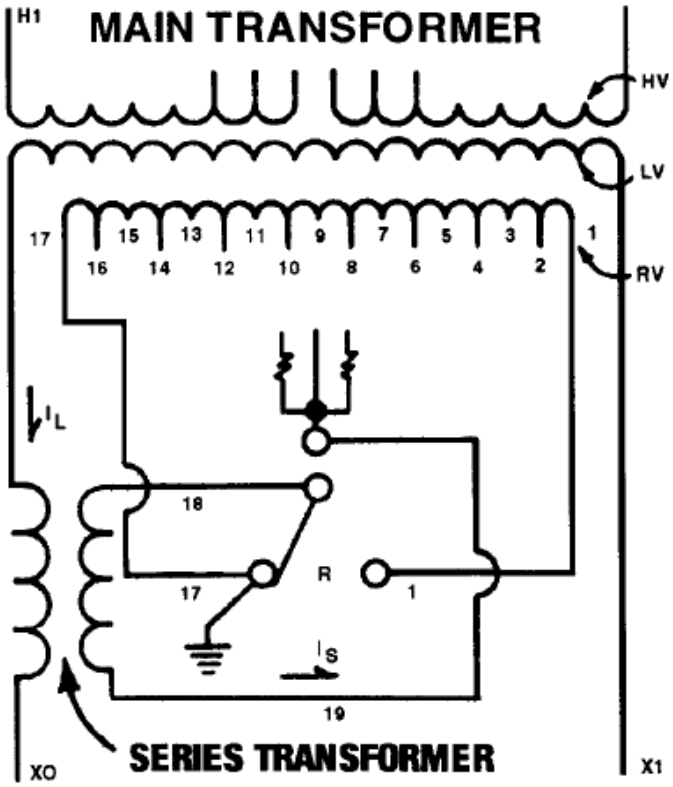

Fig. 1: Schematic of a tap changer with a series transformer

The Figure 1 shows diagram of a resistance-type tap changer with a series transformer. However, reactance-type tap changers can also utilize series transformer. Because the

transformer low voltage side has higher nominal currents than the high voltage side, it can be challenging to make a tap changer for the LV side. If the secondary circuit requires the tap changer to switch higher currents, some manufacturers opt for a series transformer. Usually, the borderline is around 600 A.
To reduce a current tap changer switches, it is placed in the same circuit with a series transformer. The current in this circuit is several times lower than a current in the transformer LV side. This is achieved by increasing a voltage of the regulating winding (marked RV in the Fig. 1) compared to required regulation percentage.

For example, if the LV winding parameters are 30 kV, 800 A, the regulating winding can be made instead of 10%, to regulate 20% of the voltage. In this case there will be 6 kV but only 400 A on the regulating winding and tap changer. This way a transformer manufacturer can install a tap changer designed for a lower current. Changing a tap position, the user selects a desired portion of 6 kV voltage on the regulating winding, to combine with the LV winding voltage lowered by half through the series transformer. The output voltage (between the points X0 and X1 in the Fig. 1) is a sum or subtraction of the voltages on the LV winding and the secondary of the series transformer. This is the way to regulate a power transformer output voltage by 10% in this case.

Measuring the Winding Resistance
Measurement of the winding resistance is one of the basic transformer tests. It is performed on the HV side by including all positions of de-energized tap changer (DETC) and on the LV side on all positions of the OLTC.
If there is a series transformer present, the winding resistance of the secondary winding will show identical result for all tap positions. The test circuit, where the tap changer is located is not electrically connected to the transformer terminals at any point. Therefore, the measurement does not include tapped winding or a tap changer. Classical approach to verification of tap changer contacts usually required lowering/draining the oil, opening the compartment, and measuring resistance on the contacts themselves.

DVtest
DVtest or a Dynamic Resistance Measurement (DRM) test is an off-line, non-intrusive test in which a DC current is injected through a transformer winding and on-load tap changer (OLTC) as it moves through its positions [1]. Results from the DC current signatures recorded with high 10 kHz sampling rate 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 extended tap changer transition time, contact problems and open circuits, among others [2]. If the tap changer is placed within the series transformer circuit, it is impossible to inject the current through it. Therefore, DVtest (DRM) cannot be performed using a standard procedure.

Motor Trigger
When performing the DVtest (DRM), there are two modes of operations available: continuous test and step-by-step test. The continuous test provides continuous recording of the dynamic resistance without performing individual static resistance measurement of each tap position. Since the series winding separates the measurement circuit from the tap

changer, the final result would be a flat straight line. This is useless for a condition assessment.
The second recording mode is a step-by-step option, where the tap change is detected, and then the current is recorded for a few seconds before and after the change. A circular buffer and at least USB 2.0 connection between a laptop computer and the instrument are required for this mode. The trigger that starts the recording is the tap changer's motor current signal. It makes it possible to record one second before the motor starts and 5 seconds after it stops. This mode of operation is called "Motor-Trigger Step-By-Step" recording.

DVtest When a Series Transformer is Present

To perform OLTC condition assessment, and obtain the DVtest (DRM) signature of tap transitions, DV Power offers its newly developed proprietary procedure. The DV-Win software has a special panel for "series transformer" testing. This mode includes several additional parameters, like "Voltage change" in percent and "Time after motor start" in seconds, as it will be explained in the further text. Once the tap operation is detected, a signal, similar to a radar beam, is sent and a reflection is recorded on the test current trace.

Since the tap changer is only magnetically coupled with the secondary winding, a steady DC current in the winding under a test will neither create any variable flux nor induce a current through the tap changer circuit. To create a current flow through the tap changer, it is necessary to provide a variable DC current value through the secondary winding. This creates changes of magnetic flux and generates a current in the tap changer circuit. Any change in this current, such as change/ripple during transition, will be reflected through the series transformer into the secondary winding DVtest (DRM) current that is being recorded.
The variable DVtest current is generated in the following way: during each transition, the test voltage, and therefore the test current, is automatically decreased for a predefined percentage ("Voltage change") after a predetermined period ("Period after the motor start"). The test voltage (and the test current) is maintained at this lower value for 5 seconds. During this time window, the user should observe a ripple graph. The waveforms will have different shapes depending on the inductance and other parameters of the transformer. [3] Adjusting those two parameters in the software will make the ripple more pronounced, and easier to analyse.

DVtest Graph Analysis

In general, the ripple is minuscule compared to the current drop created by the algorithm, as can be seen in the graph of the Figure 2 below.

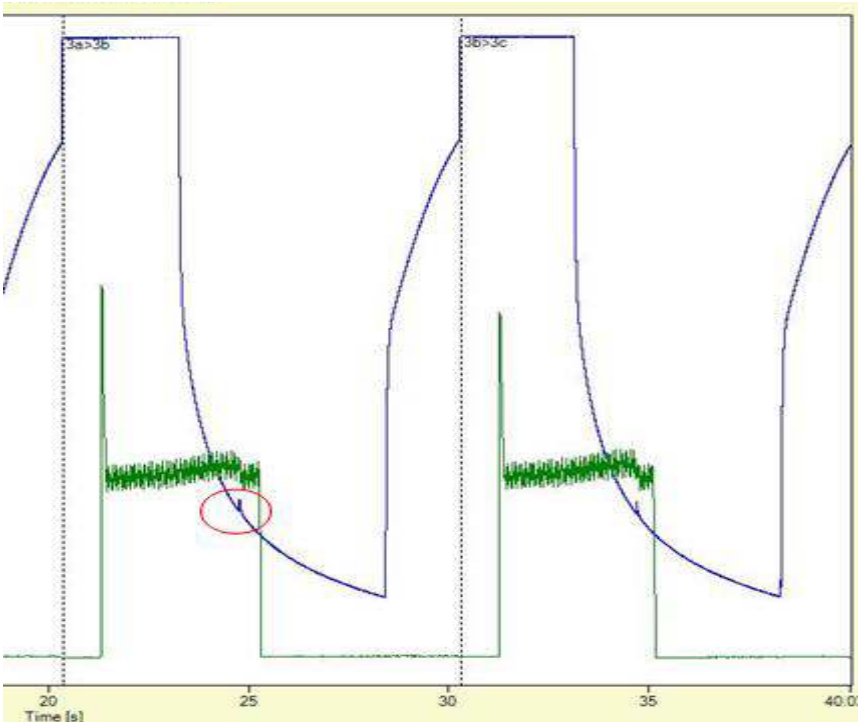

Fig. 2: Series transformer DVtest graph, a transition is marked with the red circle, motor current is green

The ABB tap changers UZERT are “resistive types” where resistors are inserted in the circuit during the transition from one to the other tap position. During the “series transformer” special test procedure, each transition creates a reflection in the main test circuit, as shown in the Figure 3. A mirror image of the transition graph is evaluated by observing the graph shape and transition times. The transition time comprises of three segments: resistor R1 carries the load, resistors R1 and R2 carry the load in parallel, and the resistor R2 carries the load, before the main contacts make firm connection. On the DVtest graph it can be easily observed where the current goes into recovery. Tap changer contacts’ resistance cannot and should not be measured because the tap changer is not in the electric circuit of the test loop. [3]

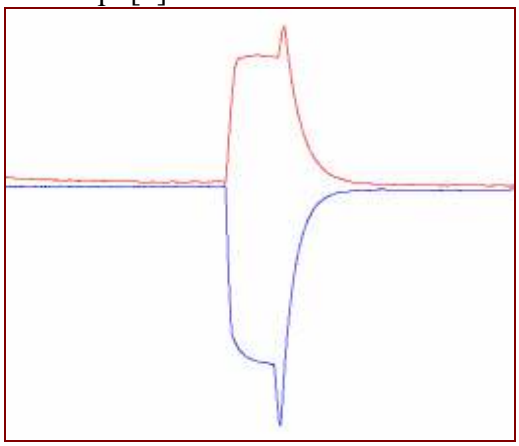
Fig. 3: Regular transition (blue) and the mirror image (red)

The Figure 4 shows a complete graph of the DVtest (DRM) on one phase of the power transformer. The ripple changes its direction from lower taps to higher taps. It is not a

surprise, although normally a ripple develops in the same direction. This may be attributed to two processes. The first is the DC current stabilization of two separate windings – the secondary winding of a power transformer, and the series transformer circuit with the tap changer. The second is change of parameters of the series transformer circuit as taps are being selected, changing the time constant [L/R] of the circuit.

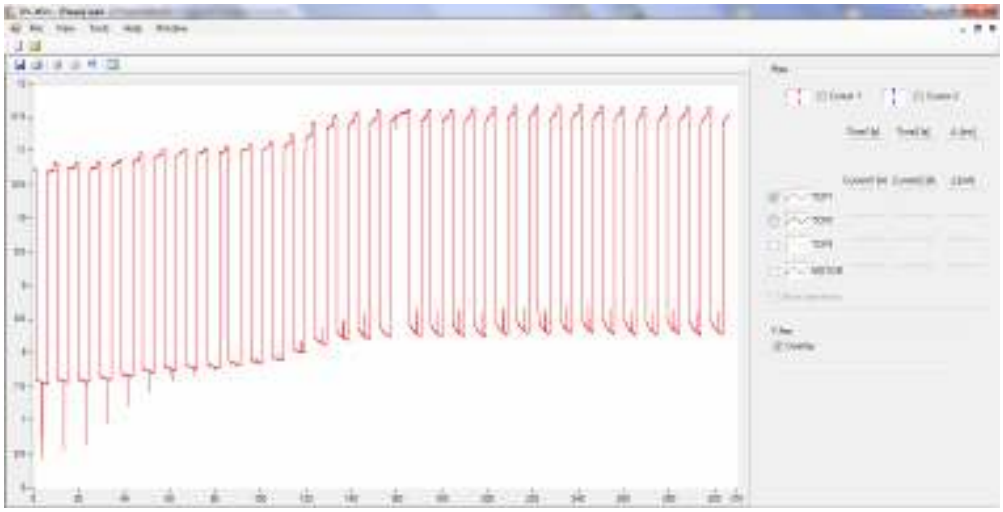

Fig. 4: Complete DRM graph of phase X1-X0 with series transformer

Finding a Problem

As DVtest (DRM) is a new methodology, a small database of signature graphs exists. For that reason the evaluation is based on comparison of ripples between transitions. This is done on a resistance-type tap changer between all ripples, while for the reactance tap changer odd ripples are compared to odd, and even ripples are compared to even ones. This is due to the inherent bridging and non-bridging tap positions in the reactance tap changer.

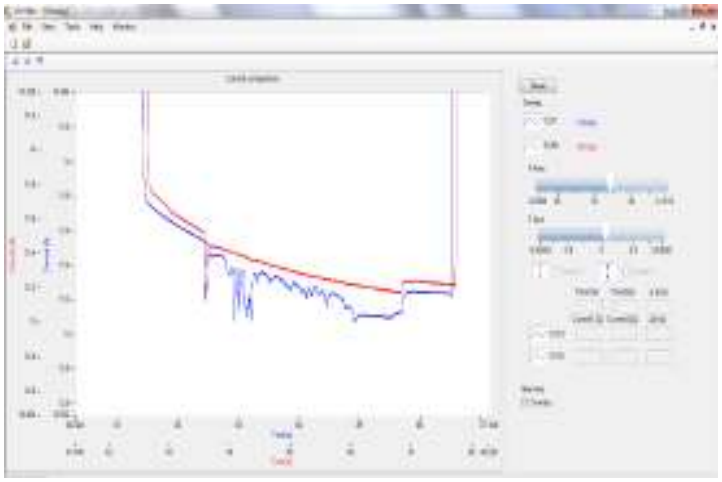

Figure 5. Bad (blue) and good (red) DVtest (DRM) traces

Figures 5 and 6 show two ripples, red and blue, where one is a clean trace while the other shows disturbances symptomatic of a bad contact – wear, bouncing or even coking.

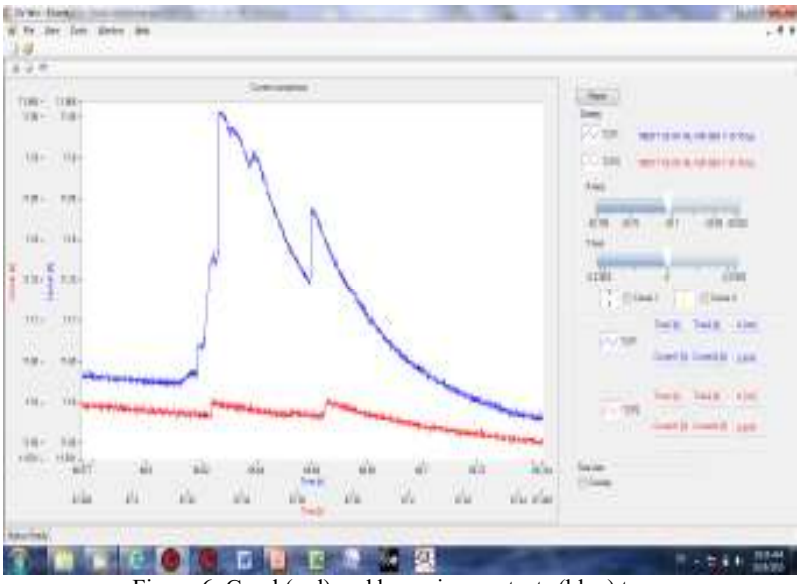

Figure 6. Good (red) and bouncing contacts (blue) trace

One benefit of testing a three-phase power transformer is the fact that traces of DVtest (DRM) graphs can be compared among the phases, and any deviation is an indication that the tap changer may be performing badly.

Conclusion

The series transformer circuit with the tap changer is not electrically connected to any of the transformer bushings. Therefore, it is impossible to measure the tap changer contact resistance without opening the tap changer. For that reason, this specific DVtest (DRM) solution is an ideal way of assessing the condition of a tap changer with no need to open it [4]. In addition timing of OLTC and contact bouncing can be observed as well.

References

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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

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